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U.S. DEPARTMENT OF COMMERCE  
Environmental Science Services Administration  
Research Laboratories

## An Atlas of Oblique-Incidence High-Frequency Backscatter Ionograms of the Midlatitude Ionosphere

ROBERT D. HUNSUCKER

BOULDER, COLO.  
MARCH 1970



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## ESSA TECHNICAL REPORT ERL 162-ITS 104

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INSTITUTE FOR TELECOMMUNICATION SCIENCES  
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March 1970


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# AN ATLAS OF OBLIQUE-INCIDENCE HIGH-FREQUENCY BACKSCATTER IONOGRAMS OF THE MIDLATITUDE IONOSPHERE

Robert D. Hunsucker

An atlas of data photographs of oblique-incidence high-frequency (HF) backscatter ionograms of the mid-latitude ionosphere from the period 1952 - 1969 is presented. Representative examples of data acquired by the range-azimuth scan, range-elevation scan, range-time, sweep-frequency and PPI backscatter techniques are displayed. No attempt is made to interpret the backscatter "signatures", but publications which present analyses and interpretations of backscatter data are referenced.

Key Words: Atlas, backscatter, data, high-frequency, ionograms, ionosphere, midlatitude, oblique-incidence, photographs.

## 1. INTRODUCTION

The purpose of this report is to present representative examples of oblique incidence backscatter ionograms of the midlatitude ionosphere obtained by several different high-frequency (HF) backscatter sounding techniques. The atlas consists of five data photosections and an appendix. Each section contains a description of a particular technique, a listing of pertinent equipment parameters, a sample data format and a collection of photographs of the particular cathode-ray-tube (CRT) data display. Other similar atlases have been published by Wright and Knecht (1957) and by Agy et al. (1959).

The HF backscatter technique for exploring the ionosphere was pioneered by Edwards and Jansky (1941), Benner (1949), Kono (1950), Hartsfield et al. (1950), Dieminger (1951), Peterson (1951), Abel and Edwards (1951), Villard and Peterson (1952), and Silberstein (1954). This technique continues to provide scientists with new and important information on the physics of the ionosphere and the nature of the

surface of the earth. Basically, the method utilizes an HF pulse transmitter and a suitable antenna to illuminate the ionosphere, and a sensitive receiver to detect the signal after it has been refracted in the ionosphere, backscattered from the earth and returned via the ionosphere to the receiving antenna. Direct backscatter from electron-density irregularities in the high-latitude ionosphere has also been described by Bates (1960, 1965), and applications of HF backscatter information for improving high-latitude HF predictions have been recently reported by Hunsucker and Bates (1969).

No attempt will be made to interpret the backscatter data in this Atlas; instead, I hope that ionospheric physicists of the theoretical persuasion, while wandering through this menagerie, may be attracted to one or more of the exotic specimens and feel compelled to contrive a rigorous, elegant, quantitative, and thoroughly satisfying explanation. For detailed analyses of various HF backscatter observations the reader is referred to publications by Croft (1965); Bates (1966); Croft (1967); Blair, Melanson, and Tveten (1969); Georges and Stephenson (1969); Hunsucker (1969); and papers referenced in the backscatter bibliography by Hagn et al. (1961).

The five-digit number on the lower left of each page of most of the ESSA backscatter data is the number of the negative for that page, which is on file in the Photographic Laboratory at the ESSA Research Laboratories in Boulder, Colorado. Photographic prints of any figure or figures may be obtained at a nominal charge by writing directly to the Photographic Laboratory.

Table 1 lists five of the most commonly used techniques for obtaining HF backscatter information on the state of the ionosphere. It is intended to convey some idea of the general characteristics and capabilities of each of the listed techniques.

Table 1. Ionospheric Backscatter Techniques.

Technique	Typical Frequency Range (MHz)	Typical Antenna Half-Power Beamwidths(degrees)		Characteristics	Reference and Typical Data in ATLAS
		Azimuth	Elevation		
Range -azimuth ) scan Range -elevation)	12-25	3° -1.5°	4.2° -2.1°	High angular Limited resolution scan width	Hunsucker and Tveten (1967); Tveten and Hunsucker (1969);
Range-time	Fixed frequency (HF)	20° -30° ~ 40°	-- --	Good range resolution Poor angular resolution	sections 2 & 3 Tveten (1961); Ranzi and Dominici (1963);
Sweep or step frequency	3-25 4-64	~ 20° 105°	-- ~ 60°	Resolution in frequency domain Very poor angular resolution	section 4 Silberstein (1954); Bates (1966);
Rotating antenna, PPI display	Fixed frequency (HF)	~ 40°	~ 30°	Large area surveillance resolution Poor angular resolution	section 5 Peterson, Egan and Pratt (1959);
Rotatable fixed-frequency	Fixed frequency (16 MHz)	8°	~ 15°	Quite good angular resolution (2-3 min.)	section 6 Thomas and McNichol (1960)





## 2. RANGE-AZIMUTH AND RANGE-ELEVATION SCAN BACKSCATTER

The backscatter data illustrated in this section were obtained with the narrow-beam HF scan backscatter sounder installation at the Institute for Telecommunication Sciences (ITS) at the Boulder ESSA Research Laboratories. Brief descriptions of some of the equipment parameters may be found in publications by Fitzgerald, Proctor, and Wilson (1966), Hunsucker and Tveten (1967), and Tveten and Hunsucker (1969), while a more complete documentation of the system has been presented recently by Hunsucker (1969).

### 2.1 Equipment Parameters

The ITS HF scan radar is a bistatic system with the transmitter located at Erie, Colorado (19 km southeast of the Table Mountain receiving site). Because of the large propagation distances compared with the separation between transmitter and receiver, however, this sounder may be considered to be a monostatic system. The radar system operates in the 9 to 25 MHz frequency range with pulse power outputs between 10 and 100 kW. The nominal pulse repetition frequency (PRF) is 20 pulses/sec and the pulse length is 300  $\mu$ sec. Two transmitting antennas are available for use: a single-wire terminated rhombic with a center design frequency of 15 MHz directed toward  $114^\circ$ , and a rotatable horizontally polarized log periodic antenna. The rhombic antenna is characterized by a radiation pattern with rather sharp nulls in azimuth and elevation, whereas the log-periodic antenna has a very wide beam, relatively uniform (lacking sharp nulls) in both azimuth and elevation.

High resolution in the receiving system is achieved by large-aperture, linear, uniformly spaced arrays electromechanically scanned in azimuth and elevation. Table 2 shows the important parameters of the elevation and azimuth scan system.

The geographical area scanned by the azimuth array as a function of frequency is shown in figure 1.

Table 2. System Parameters.

Azimuth Array (1392 ft aperture)

Elements: Log periodic horizontally polarized transposed dipoles

Frequency, 12-25 MHz

Gain, 5 dB above isotropic

Front-to-back ratio, 20 dB

E plane beamwidth, 72°

H plane beamwidth, 115°

Element spacing: 17.67 m

Element height above ground: 24.38 m

Boresight azimuth: 114° true bearing

Horizontal Antenna

Frequency (MHz)	Horizontal beamwidth (deg)	Main lobe elevation (deg)	Width of sector scan (deg)
12	3.0	14.8	90
15	2.3	11.8	69
18	2.0	9.8	56
21	1.7	8.4	48
25	1.4	7.1	40

Elevation Array (1000 ft effective aperture)

Elements: Same as for azimuth array

Element spacing: First element 8 m above ground and remaining  
ones successively spaced at 16 m

Boresight azimuth: 114° true bearing

Vertical Antenna

Frequency (MHz)	Vertical beamwidth (deg)	Effective elevation sector scanned (deg)
12	4.2	3-52
15	3.2	2.6-39
18	2.8	2.3-32
21	2.4	1.9-26
25	2.0	1.5-22



Figure 1. Geographical area scanned by ITS/ESSA azimuth array. Center azimuth is  $114^\circ$  east of geographical north and sector widths are shown as a function of frequency.

## 2.2 Classification of Echoes

This section contains many signatures observed using the ITS high-resolution HF backscatter sounder, and illustrates nearly all of the ground backscatter echo types encountered at this particular location for both undisturbed and disturbed ionospheric conditions. An attempt has been made to categorize these signatures into seven or eight generic types, which have been given names roughly describing their appearance on the range-azimuth record. Although the signatures being described here apply to the azimuth scan record, the elevation scan data are also included, and both are discussed in detail by Hunsucker (1969). On each of the data photos, an arrow points to the signature being illustrated.

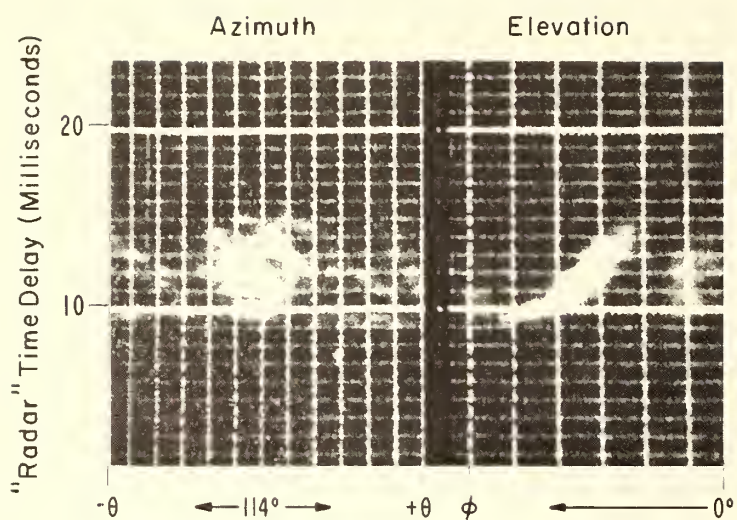
Page 11 shows examples of the "uniform" (U) backscatter signature which is characterized by a band of relatively uniform intensity at a constant range (or delay time). (The details of this particular signature are somewhat obscured by a gain saturation effect). A signature designated as a "patch" (P) is shown on pages 12 and 13. It generally has a roughly circular or elliptical shape, is always observed at ranges less than the "uniform" echo, and always appears to move approximately parallel to the range markers (left-to-right or right-to-left). Pages 14 and 15 illustrate an echo described by the name "tilt" (T), whose main identifying characteristic is its variation of range as a function of azimuth. Another often observed signature is shown on page 16 and is called "bands" (B) because it consists of two or more echoes structured in parallel bands which move in a direction perpendicular to their major dimension. They always occur at ranges greater than the "uniform" signatures and are never stationary. The signature on page 17 is categorized as "large-size-blobs" (LB), since these large echoes either remain in one position or drift slowly during their



lifetime on the azimuth scan record. Similarly, the echoes shown on page 18 display roughly equivalent movement characteristics to the "LB" signature but the "blobs" are smaller, so they are labelled "medium-sized-blobs".

Pages 19 and 20 illustrate a phenomenon called "fine-structure" (FS). These small size "blobs" always display a fast fading behavior with typical fading periods from less than 12 sec to several minutes, and display no discernible motion. Intense, short-range echoes which often saturate the azimuth-range display out to about 10 msec are shown on page 21, which was recorded during the intense Leonid meteor shower of November 15-17, 1966. The next signature illustrated in the "hook" (H) echo shown on pages 22 and 23. This characteristic shape is observed at various ranges and azimuths and represents one of the more "pathological" signatures which have been observed. Pages 24 through 27 show examples of miscellaneous unclassified signatures.

# SAMPLE DATA FORMAT



Geographic Azimuth  
Angle (Degrees East  
of North)

Degrees above  
Horizontal

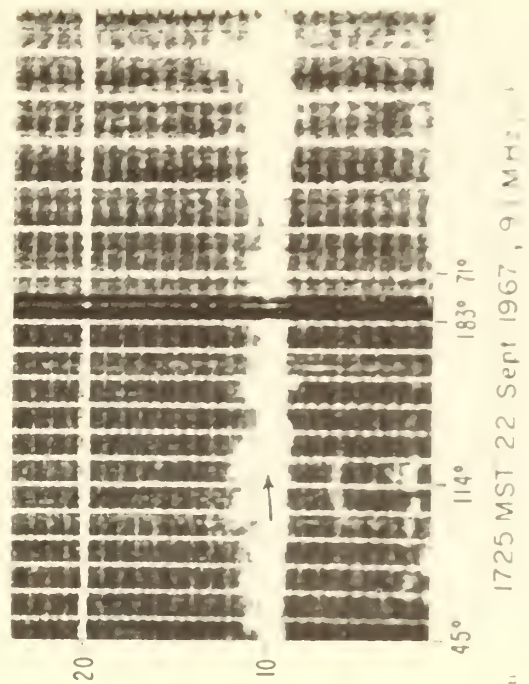
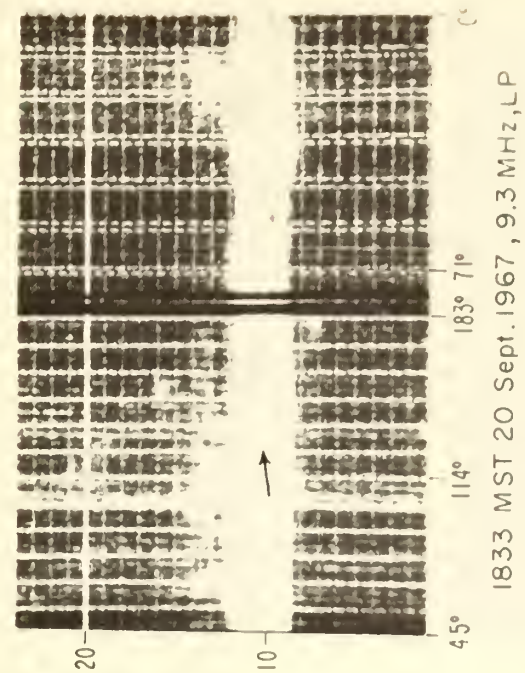
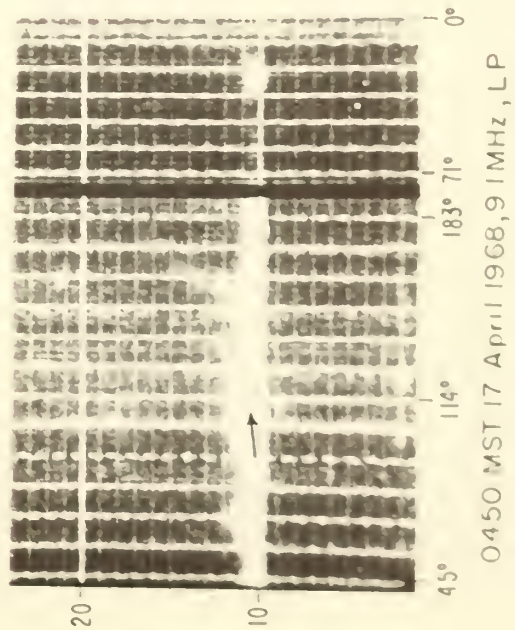
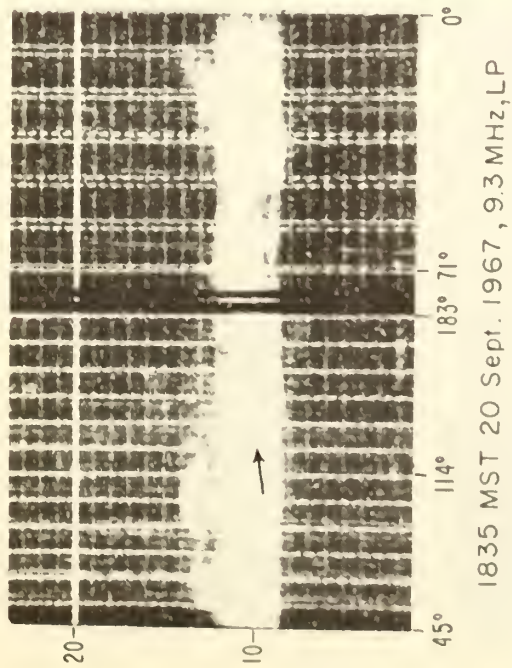
Mountain Standard Time (MST)=UT-7 Hours

Date (Day-Month-Year)

Frequency (MHz)

Type Transmitting Antenna, RH=Rhombic,  
LP=Log Periodic

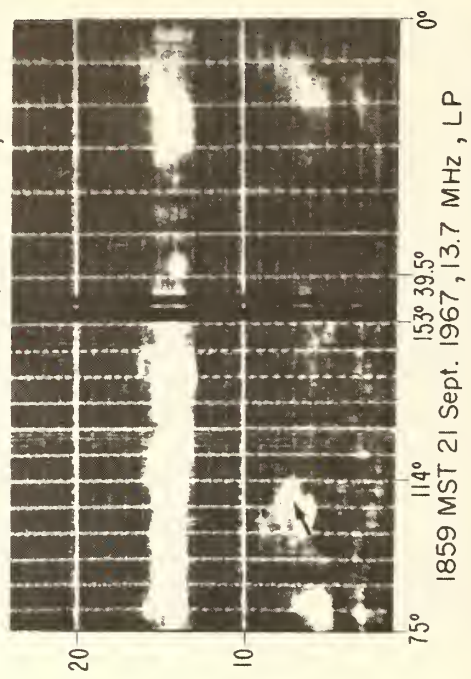
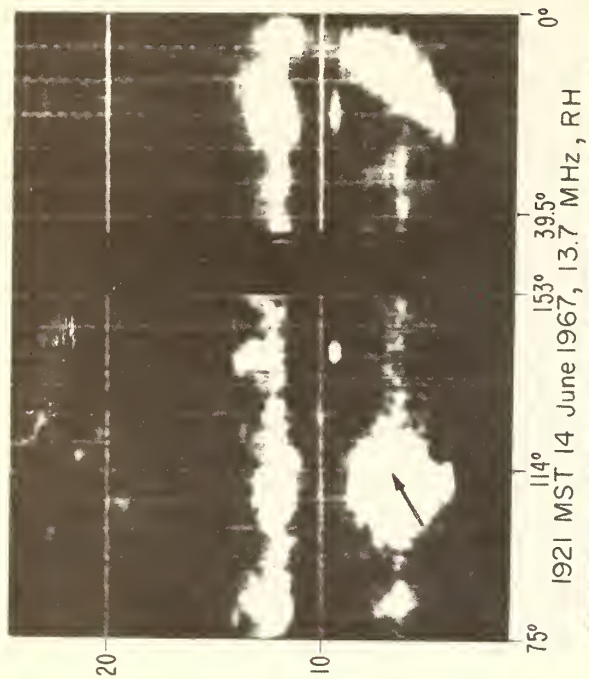
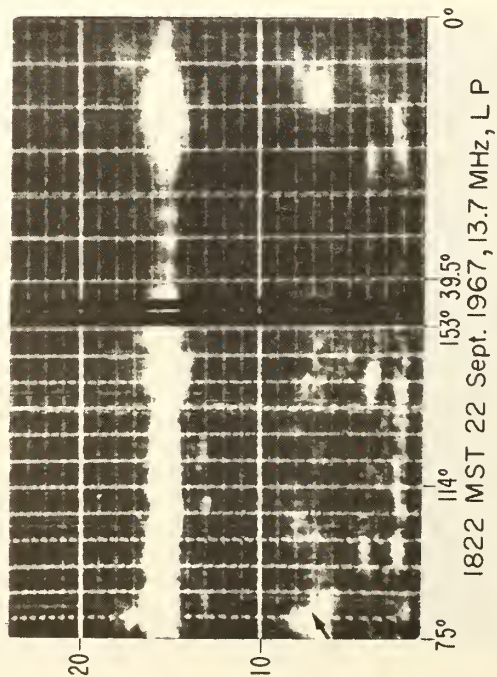
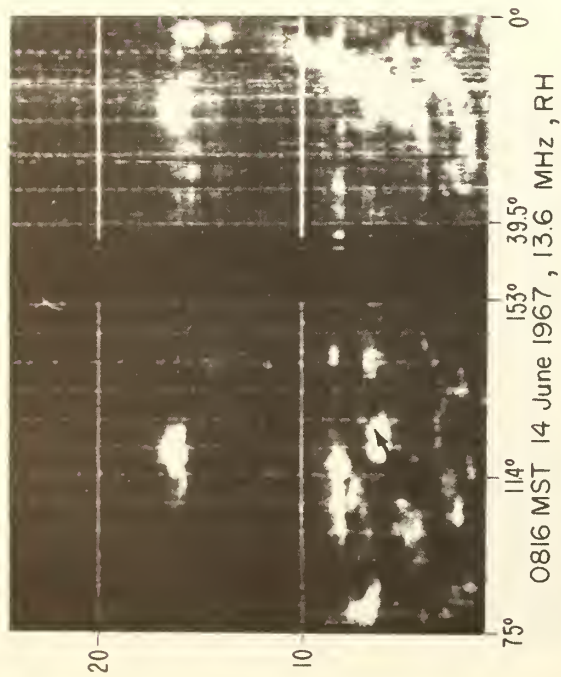
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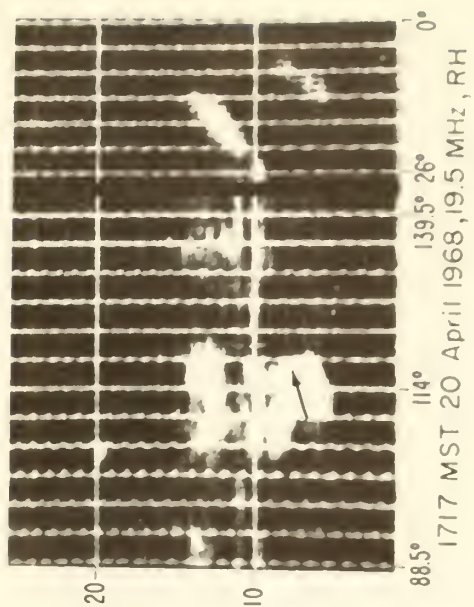
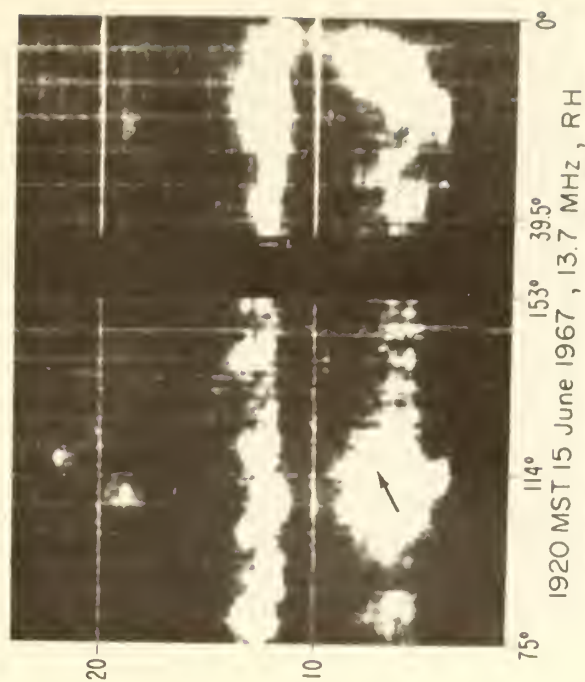
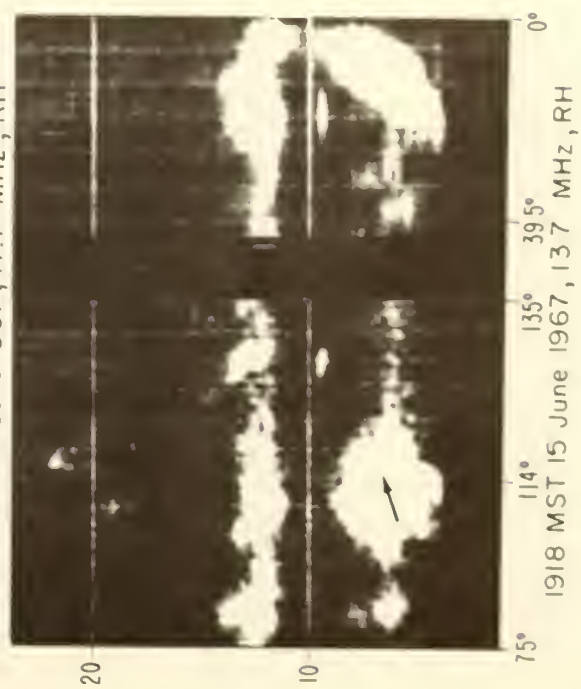
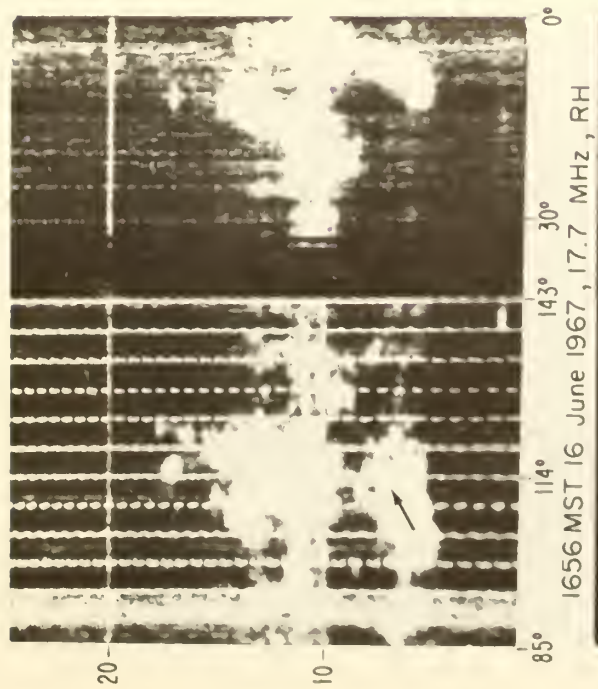
"Uniform Echo"



82818

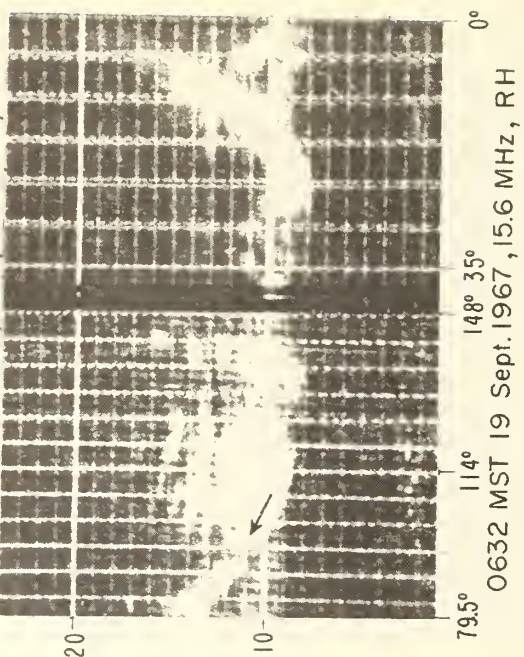
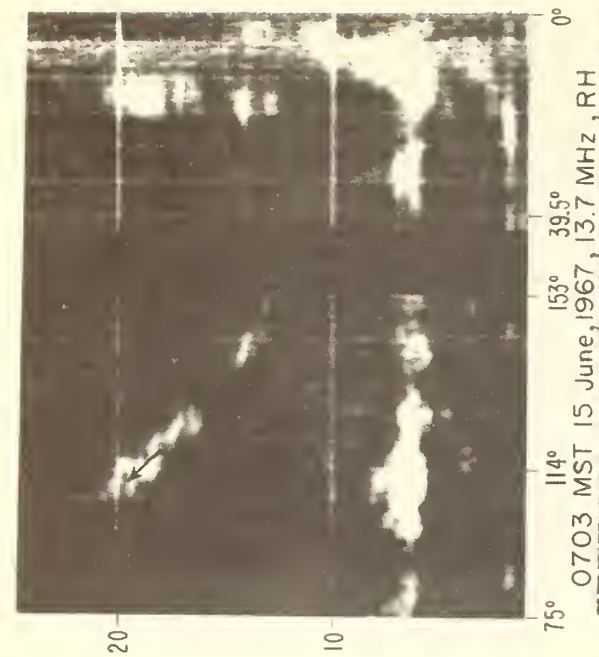
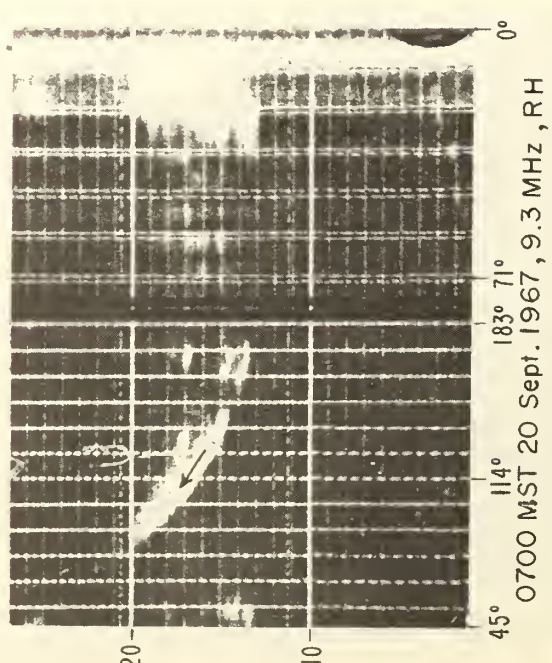
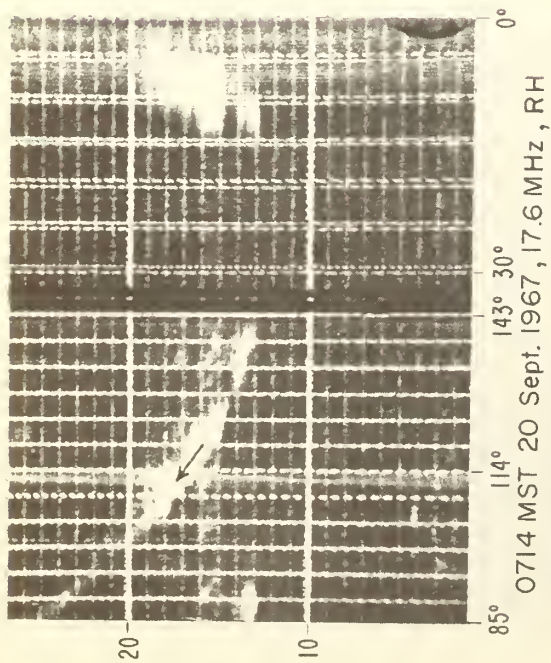


"Patches"

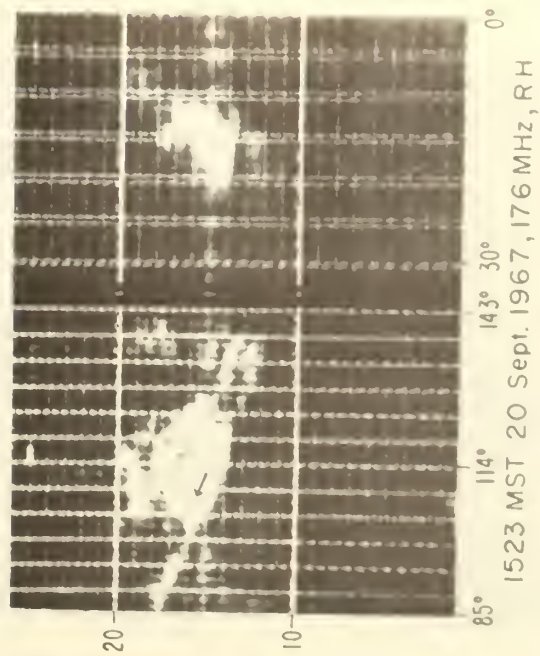


"Patches"

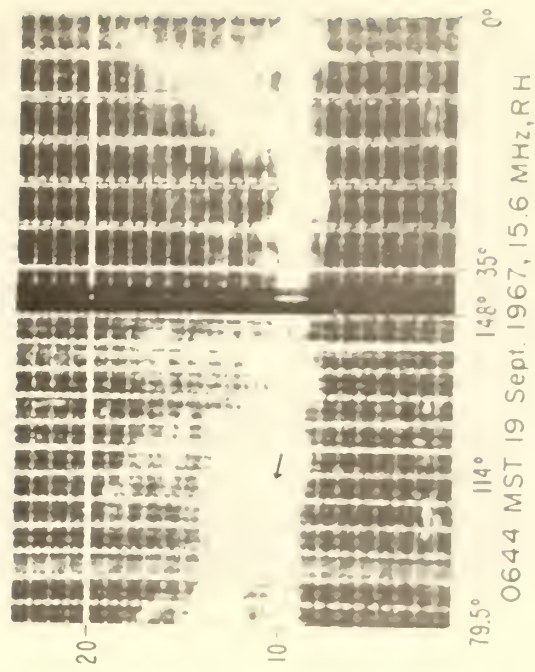




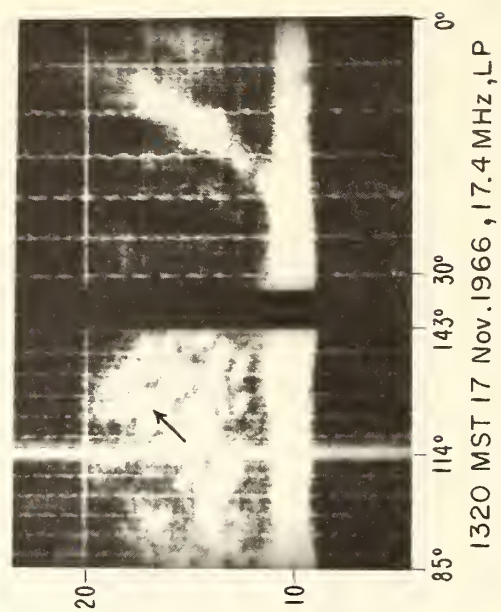
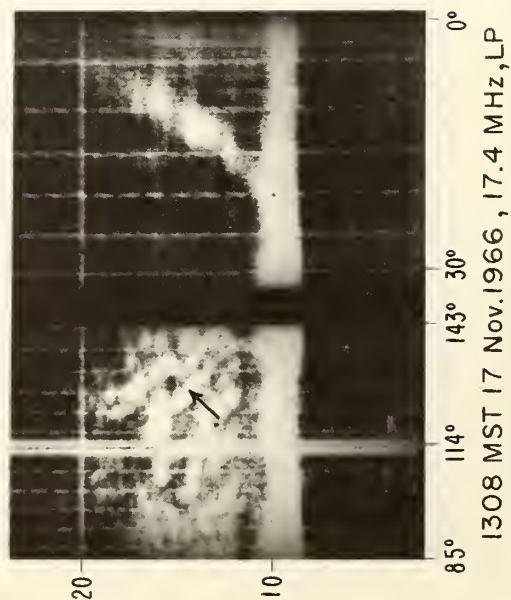
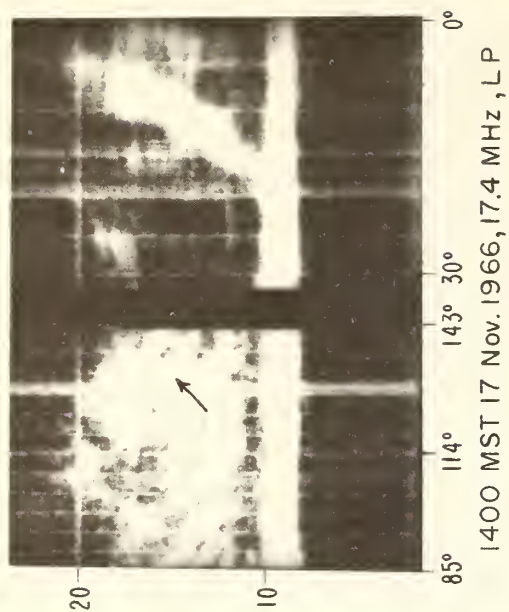
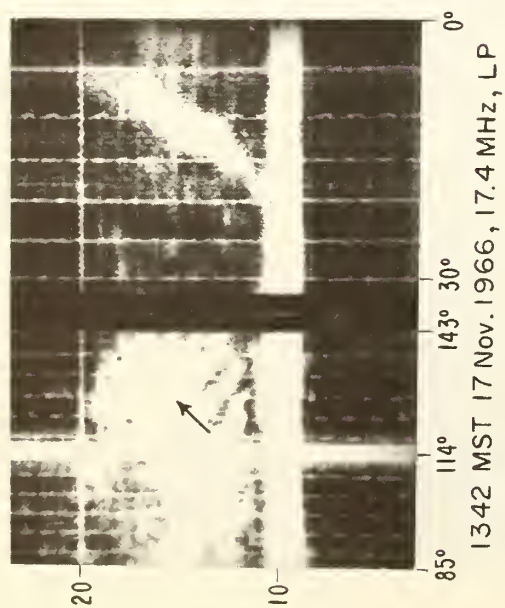
"Tilt"



"Tilt"

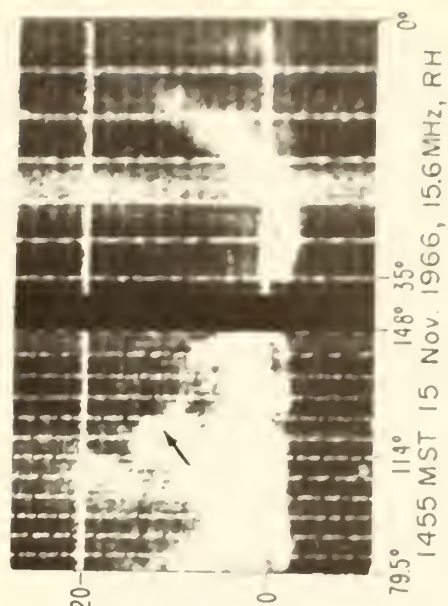
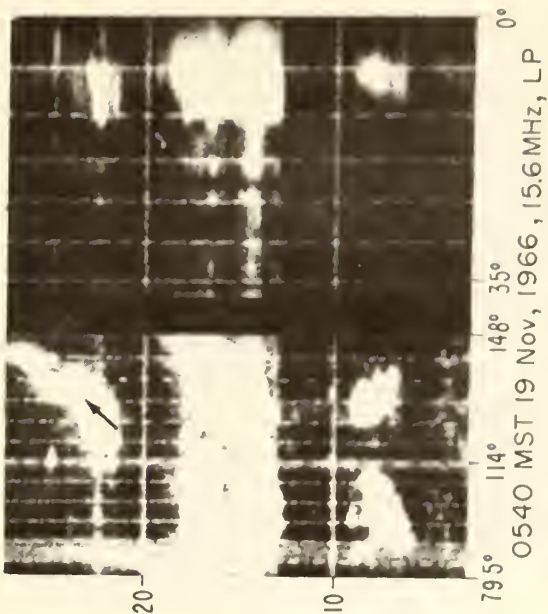
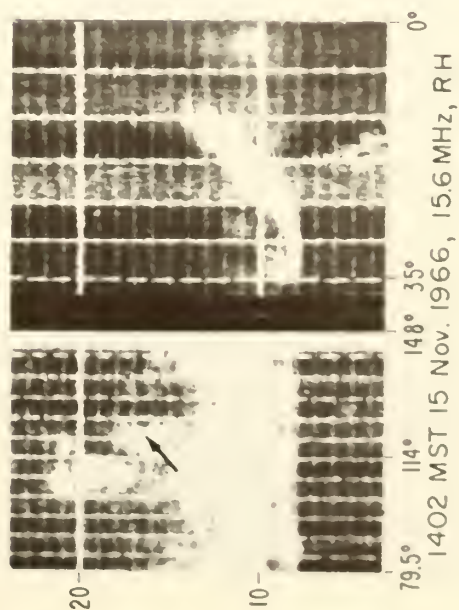
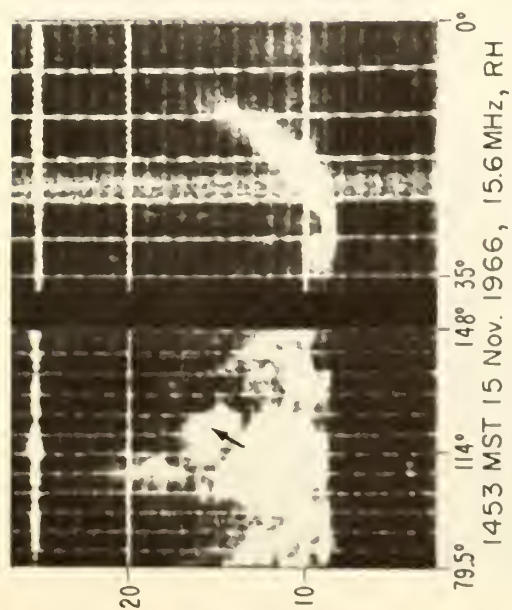


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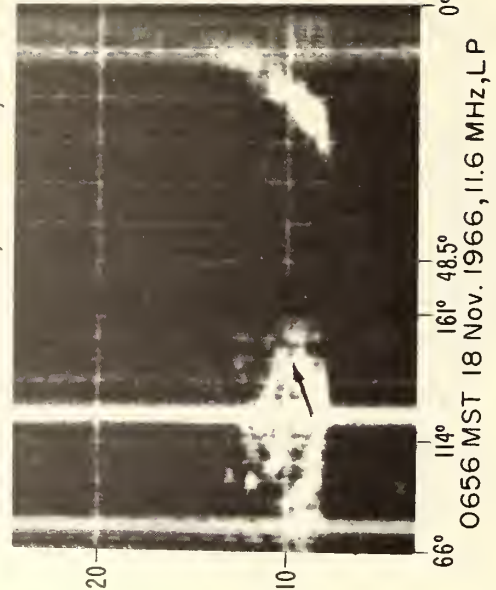
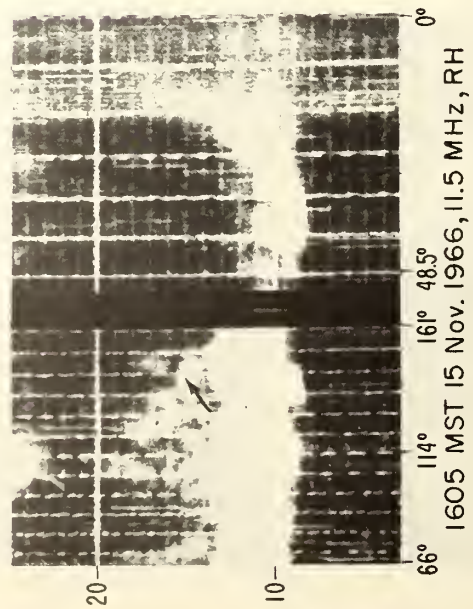
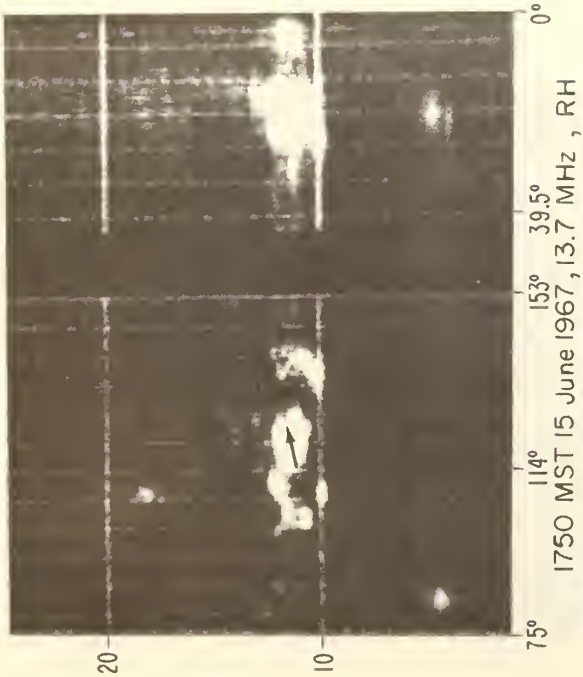


"Bands"



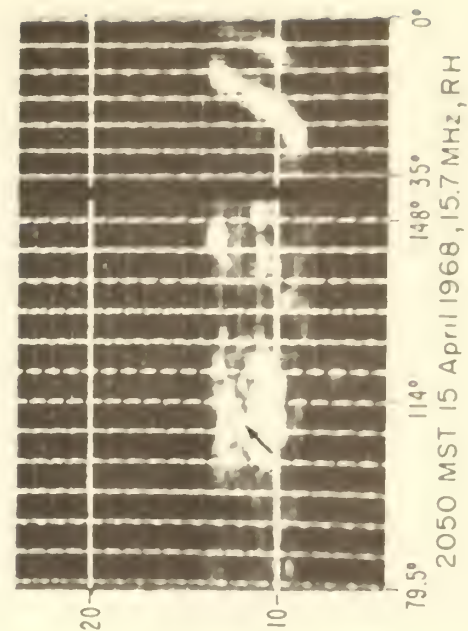
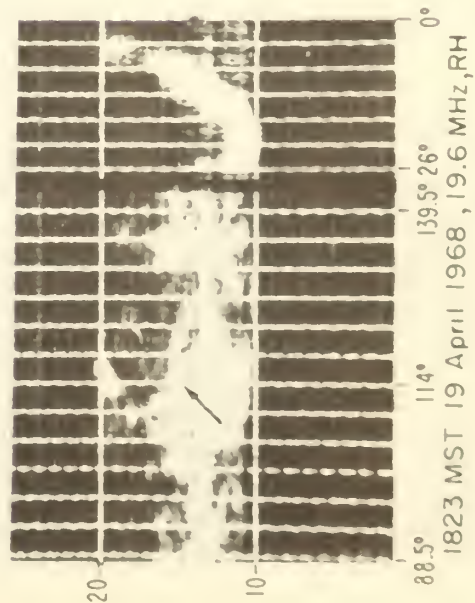
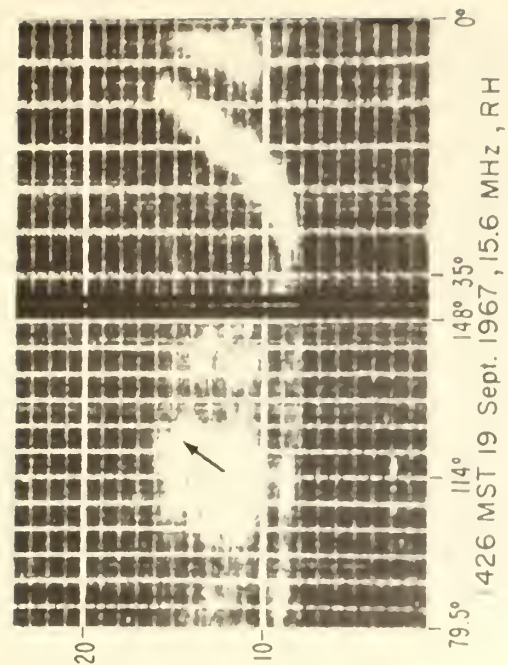
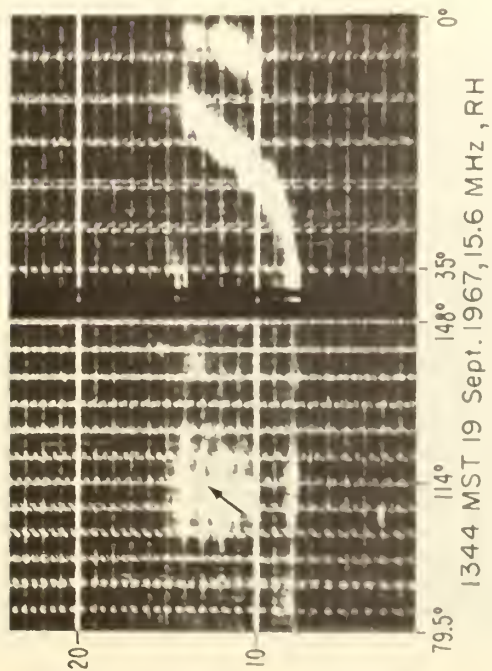


"Large Size Blobs"



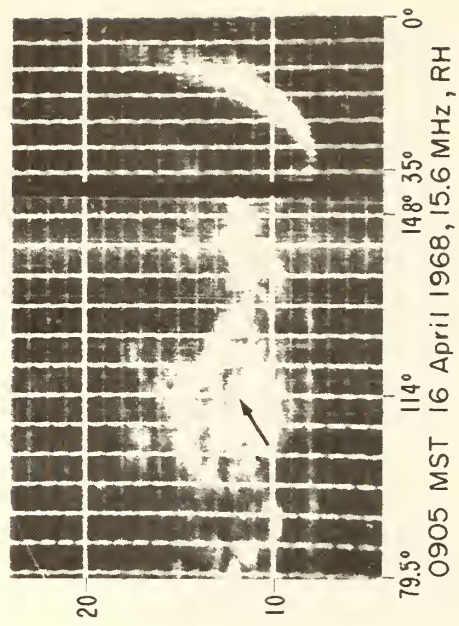
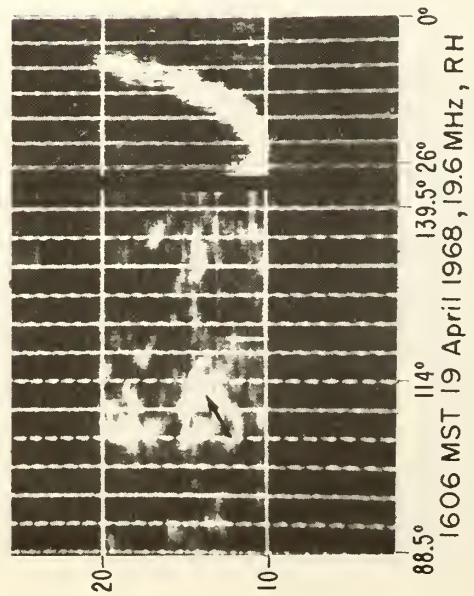
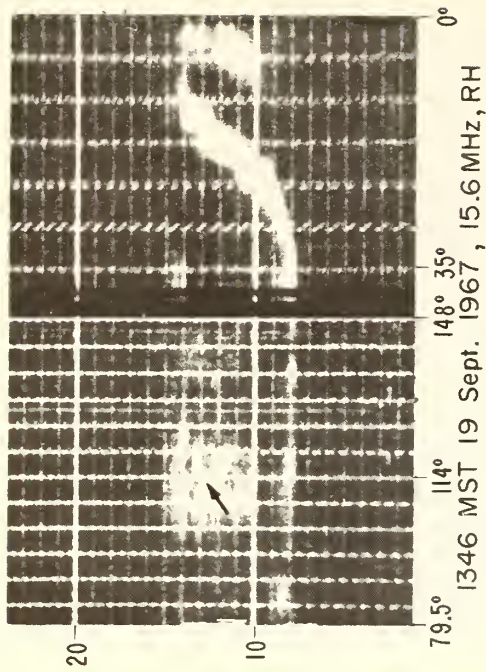
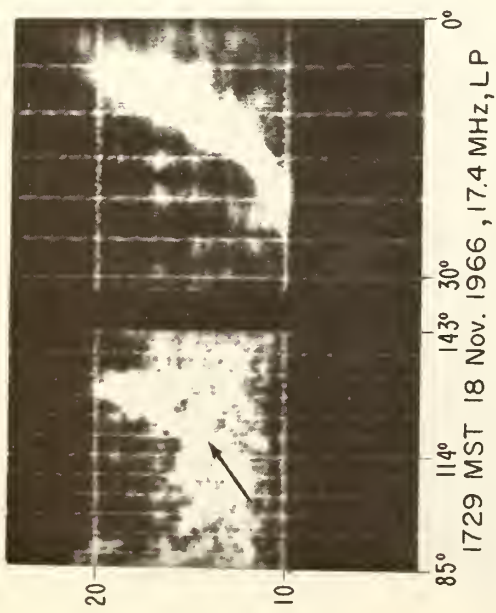
"Medium-Size-Blobs"



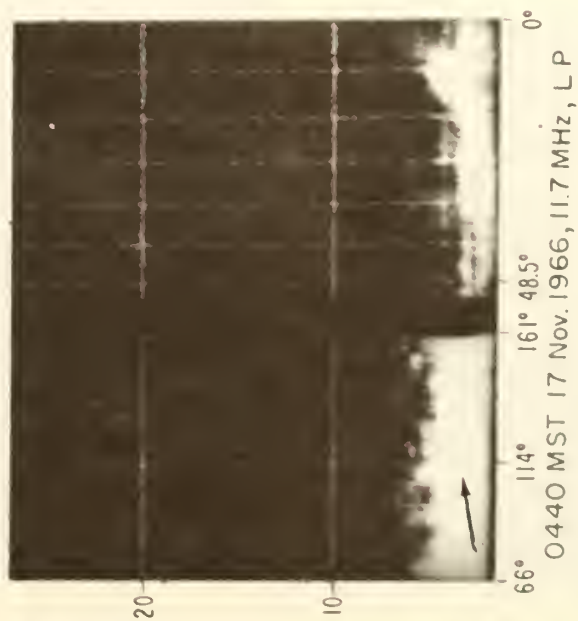


"Fine Structure"

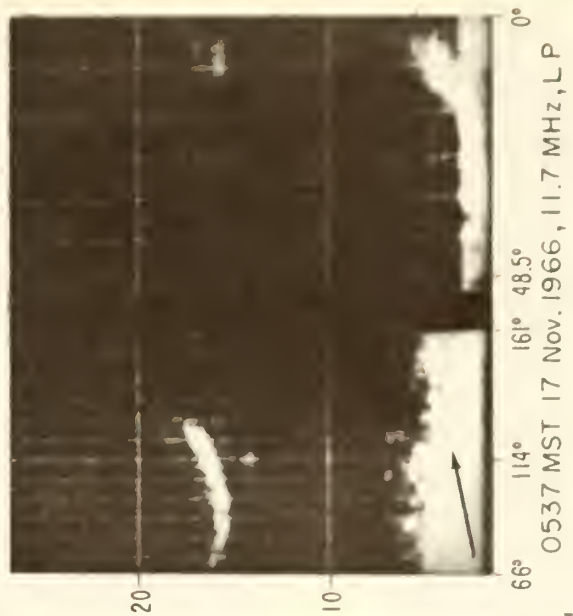
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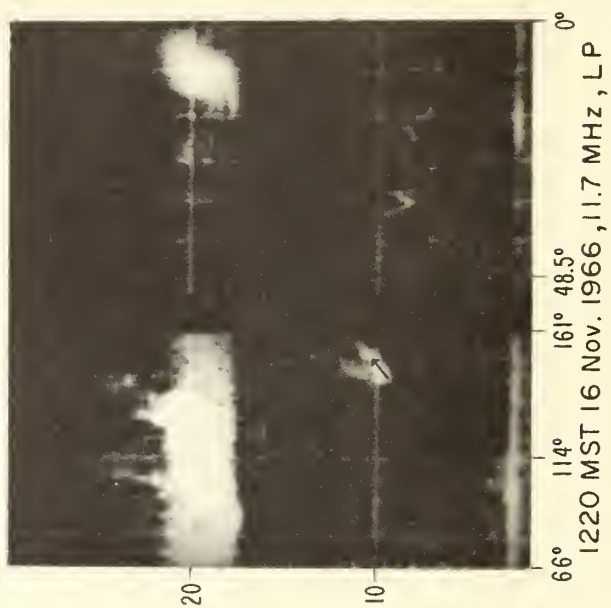
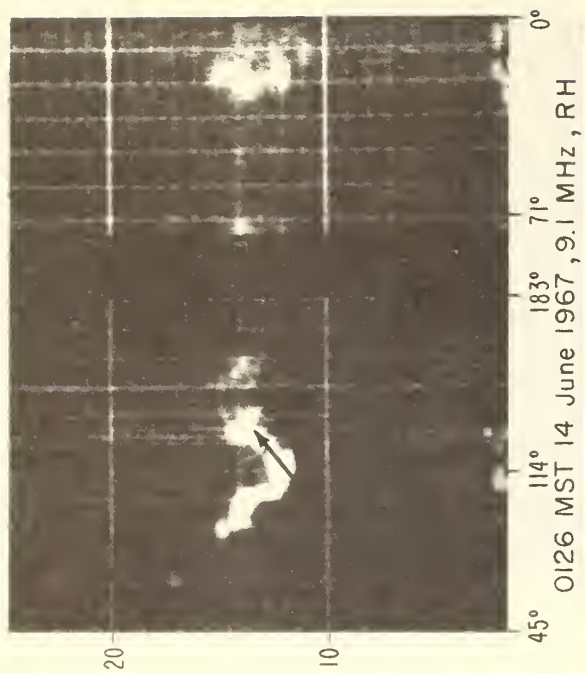
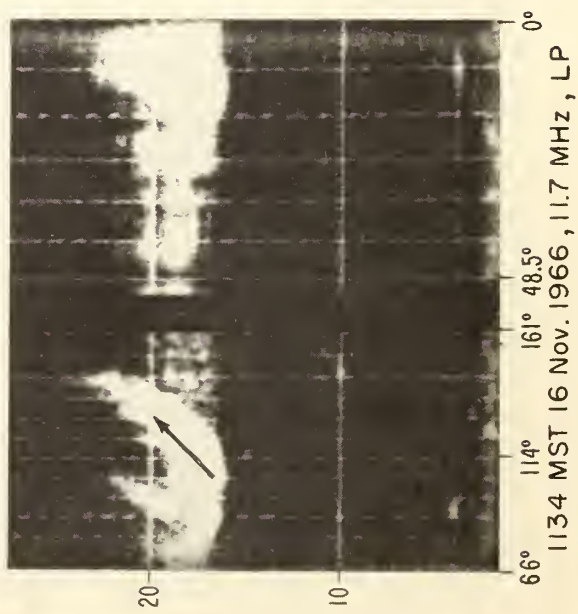
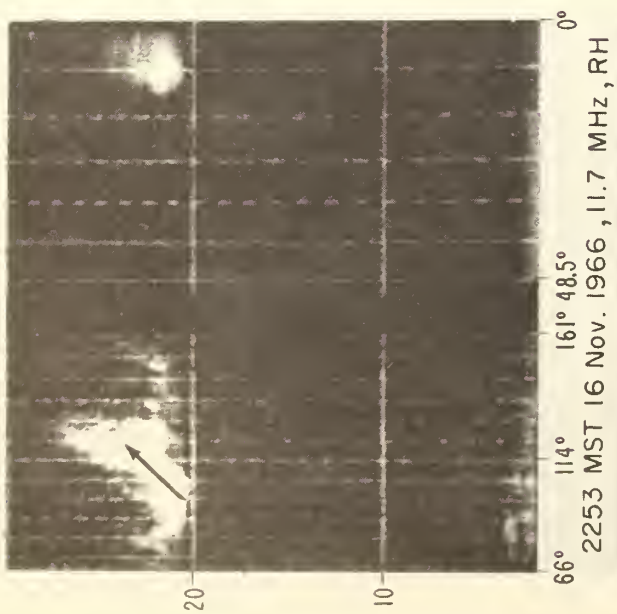
"Fine Structure"



"Short-Range - Echo"

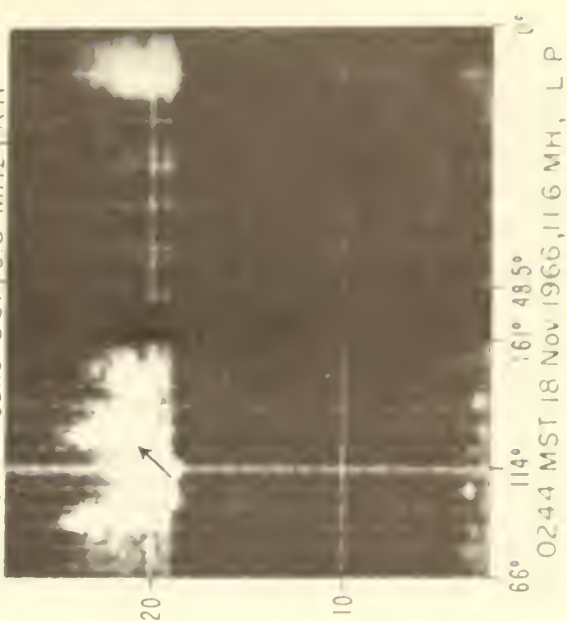
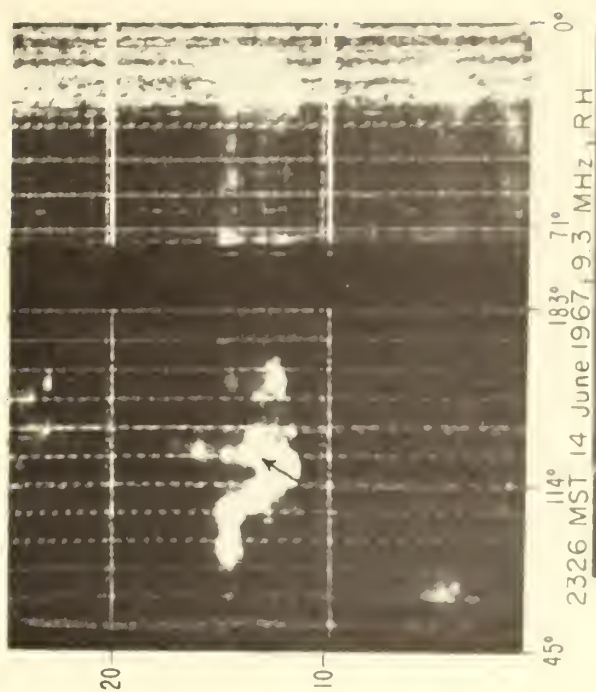
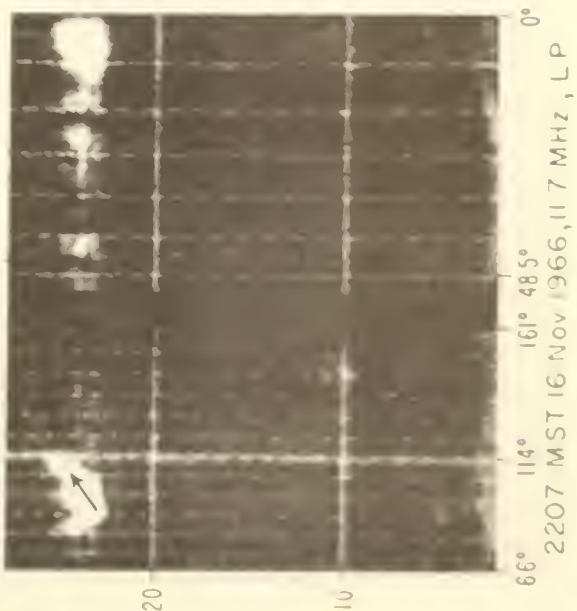
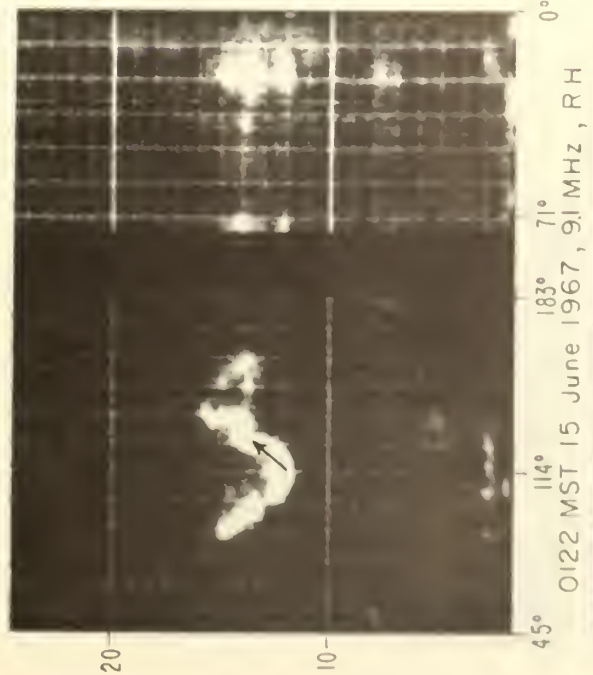






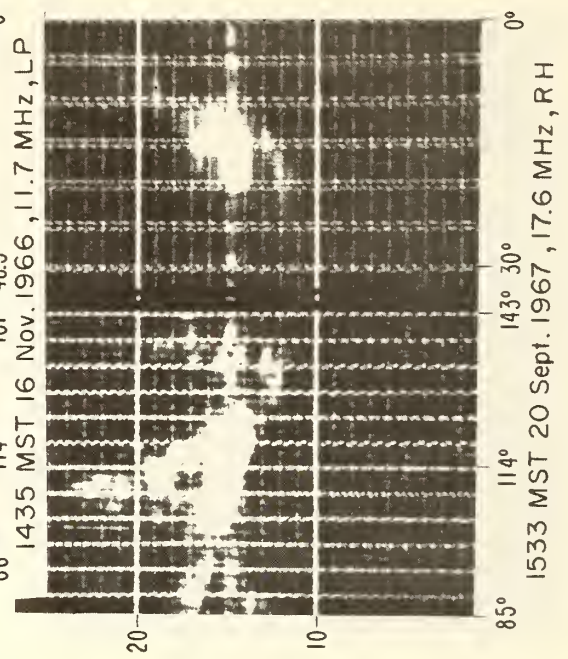
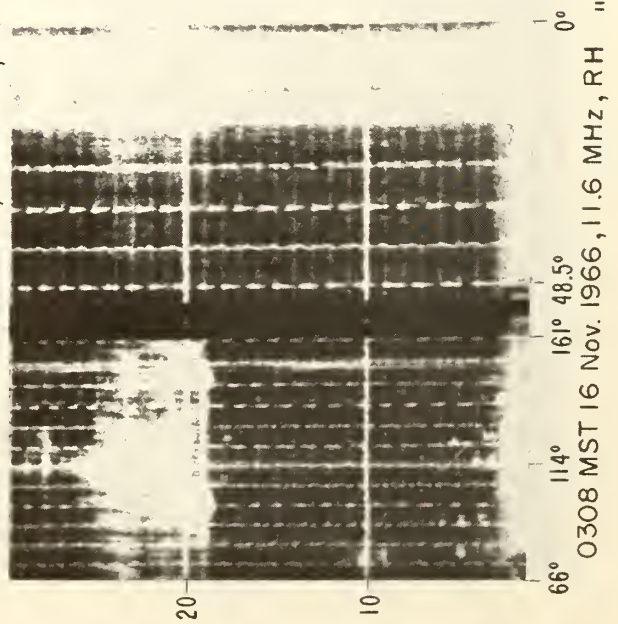
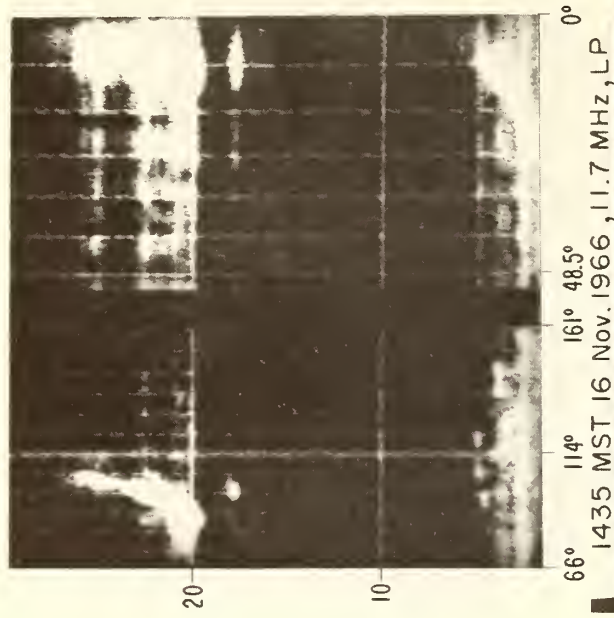
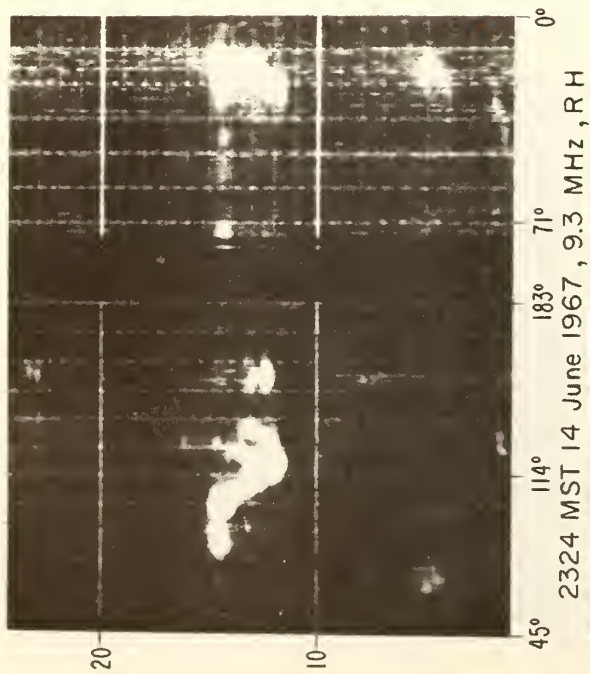
"Hook"



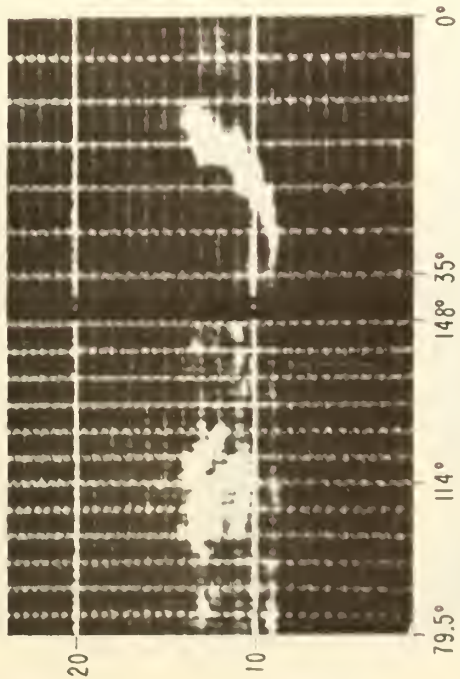


"Hook"

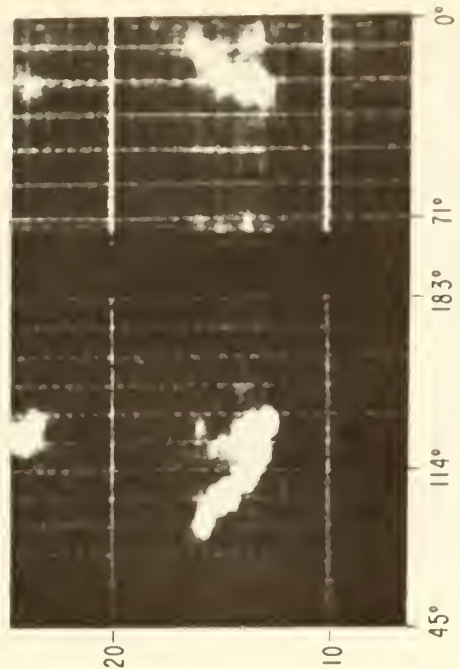
82831



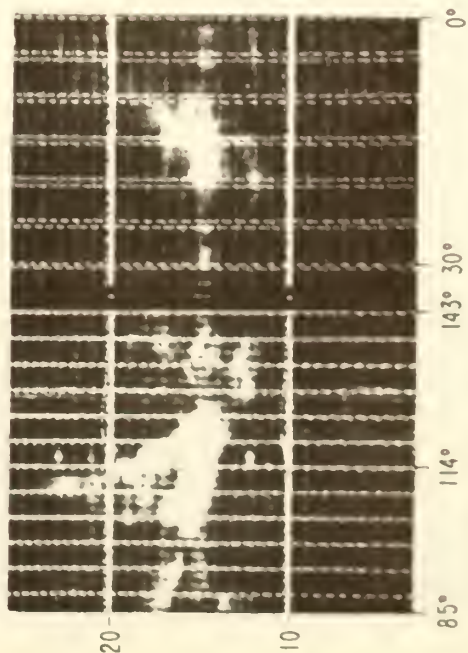
"Unclassified Echoes"



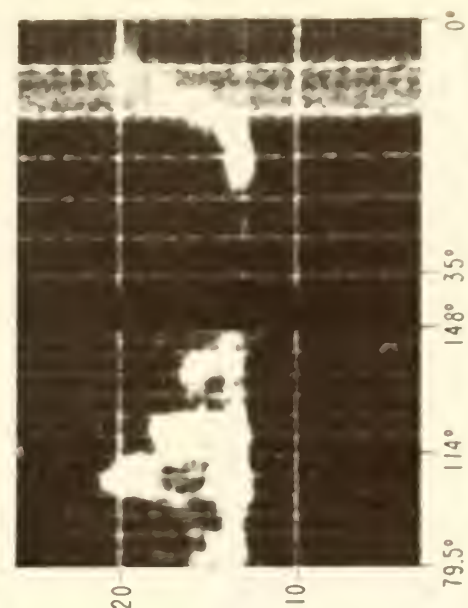
1531 MST 23 Sept. 1967, 15.6 MHz, RH



0352 MST 14 June 1967, 9.1 MHz, RH



1531 MST 20 Sept. 1967, 17.6 MHz, RH

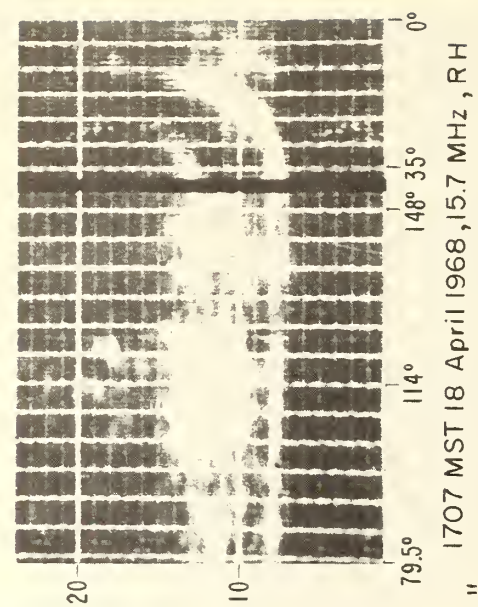
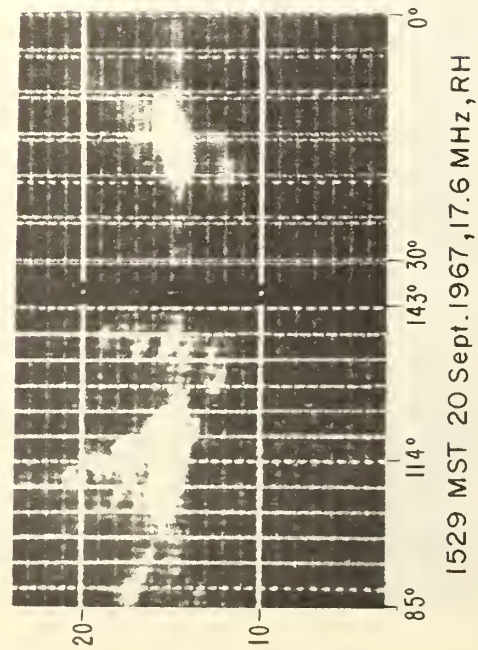
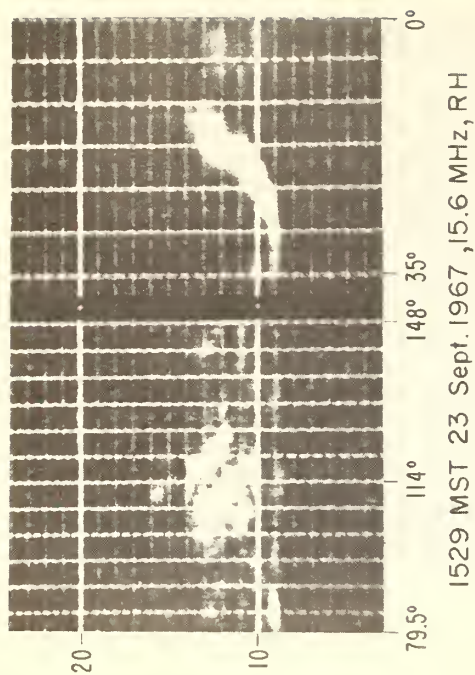
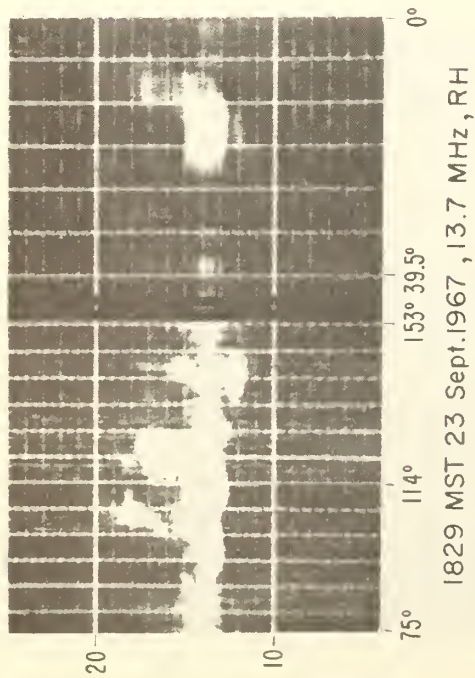


1612 MST 15 Nov. 1966, 15.6 MHz, RH

"Unclassified Echoes"

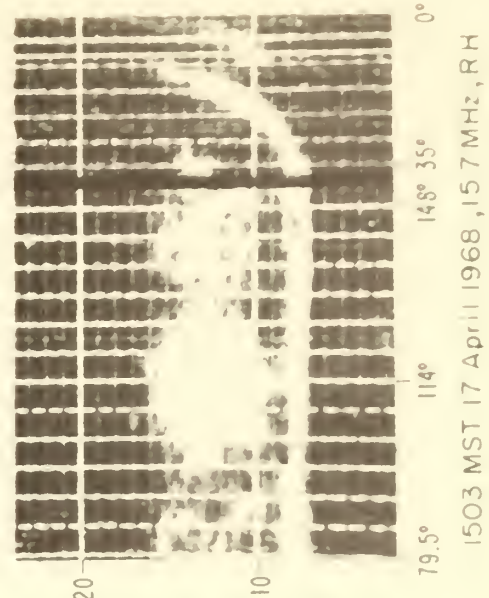
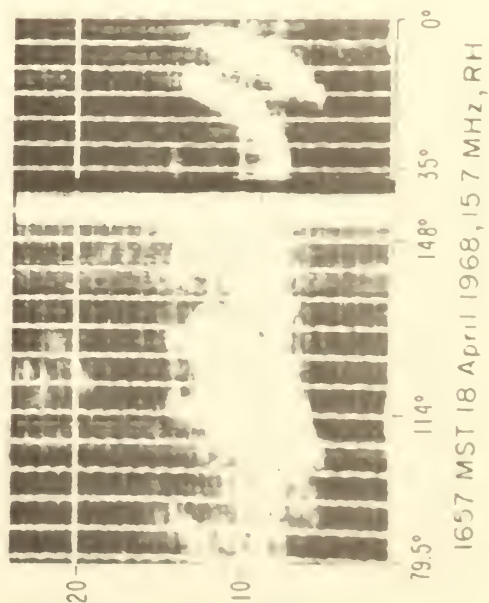
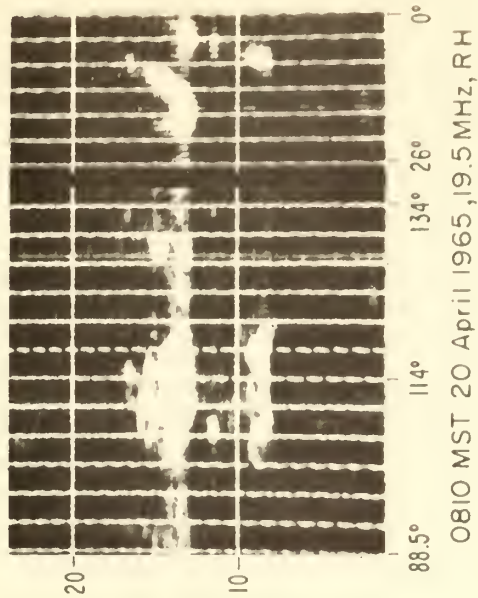
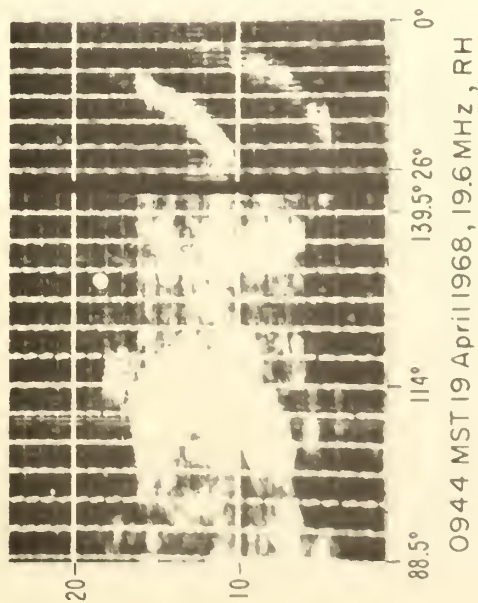


82833



"Unclassified Echoes"



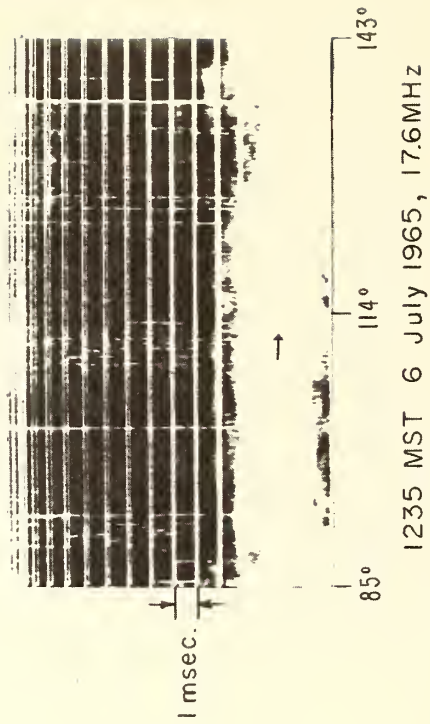
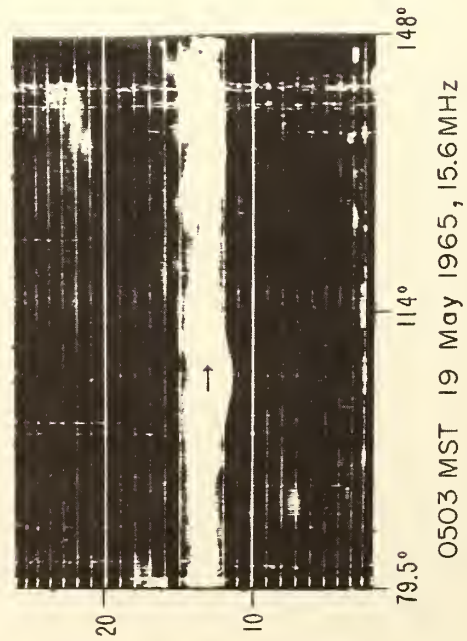
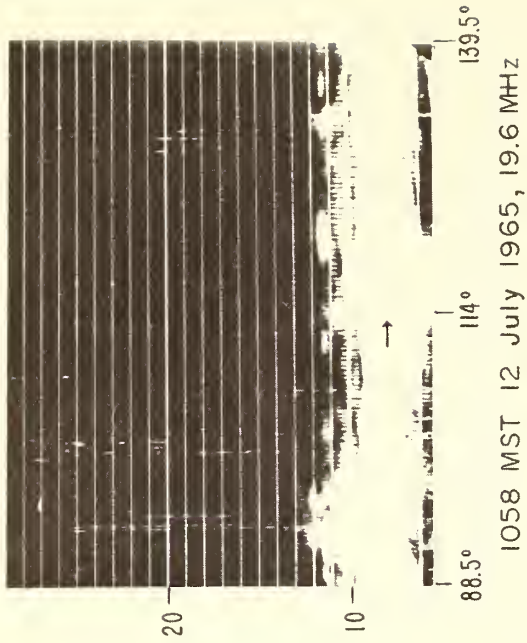
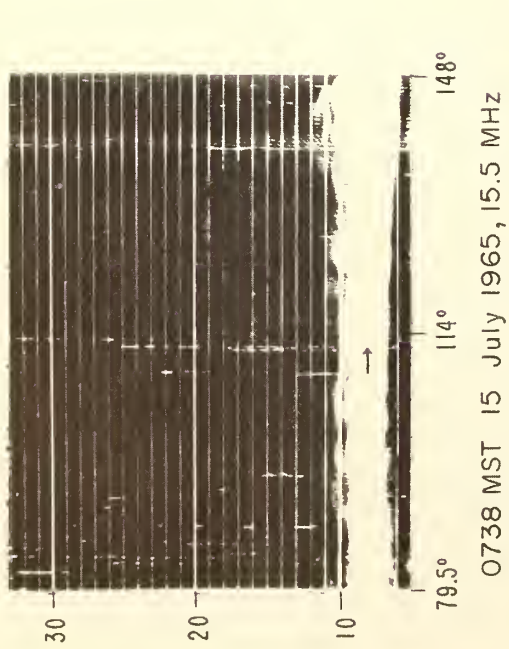


"Unclassified Echoes"



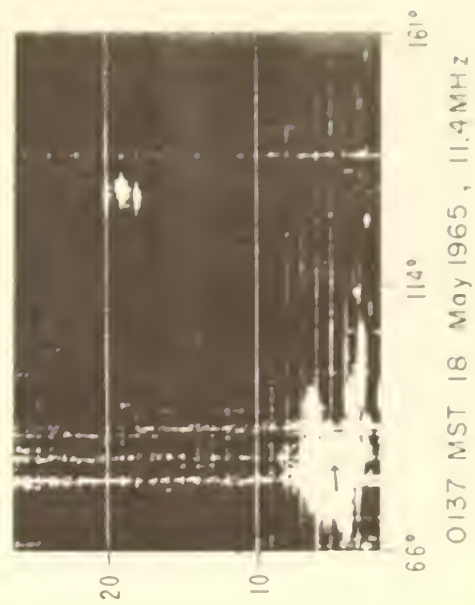
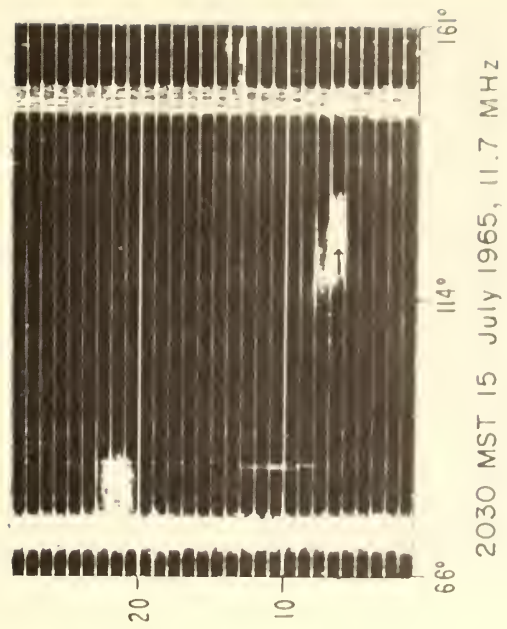
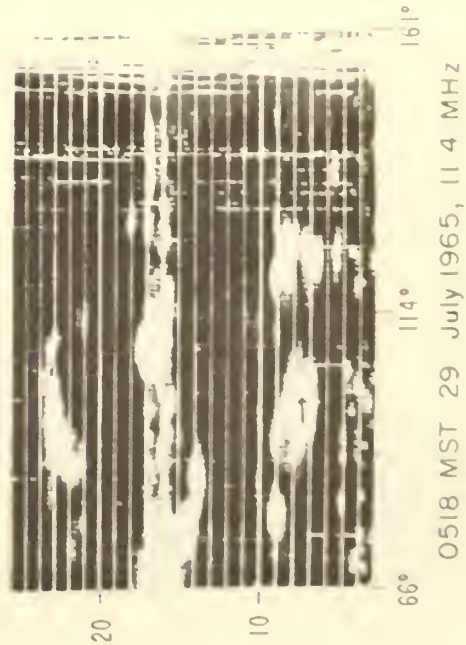
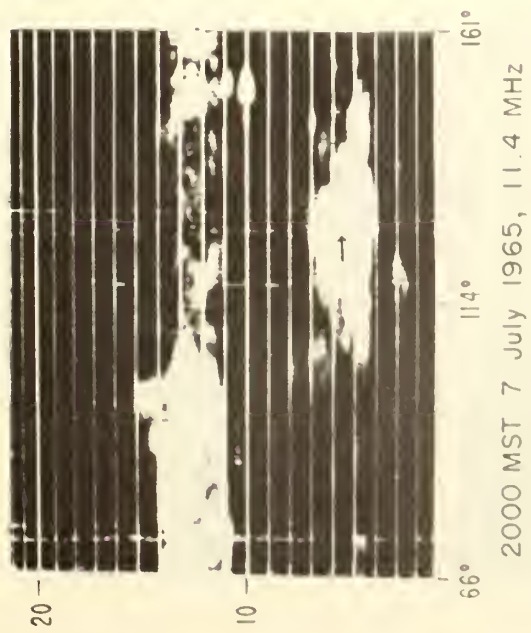
### 3. RANGE -AZIMUTH SCAN BACKSCATTER

The data displayed in this section are identical to the range-azimuth format displayed on the left of page 10, and were obtained by the technique described in section 2. The same equipment parameters and echo classifications are applicable to sections 2 and 3. The data in this section were photographed on 35-mm film, as opposed to the data in section 2, which were photographed (both range-azimuth and elevation-azimuth scans) on 16-mm film. The fine details of echo structure should therefore be more easily identified on the data in this section. The echo types are arranged in the same sequence as in section 2.



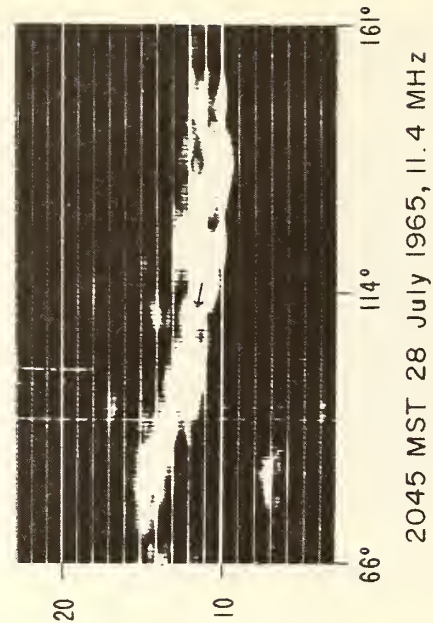
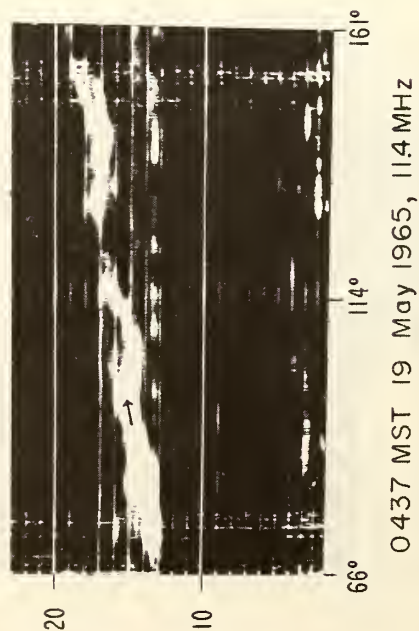
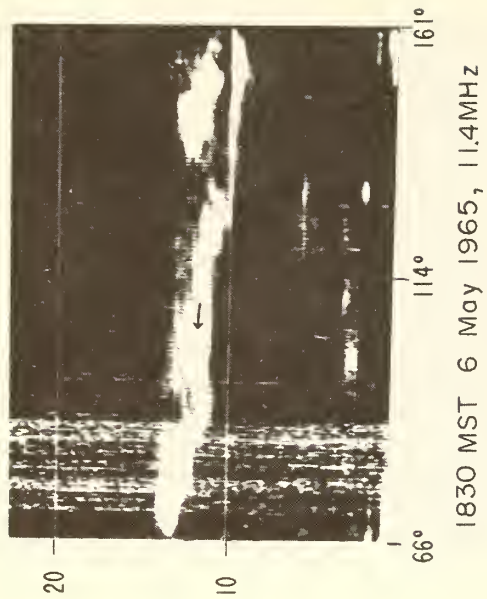
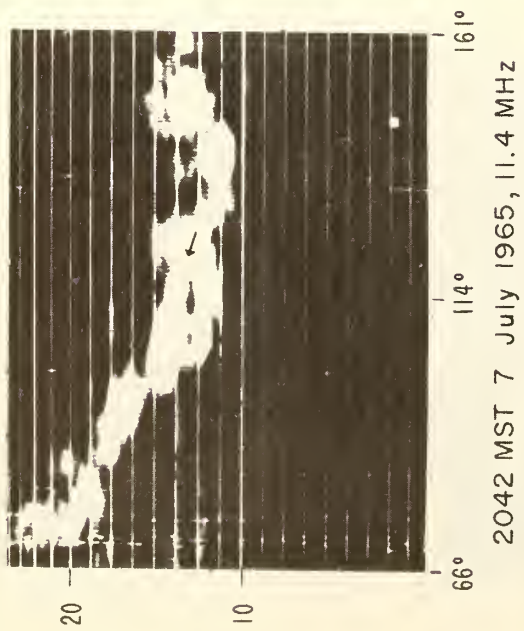
"Uniform Echo"



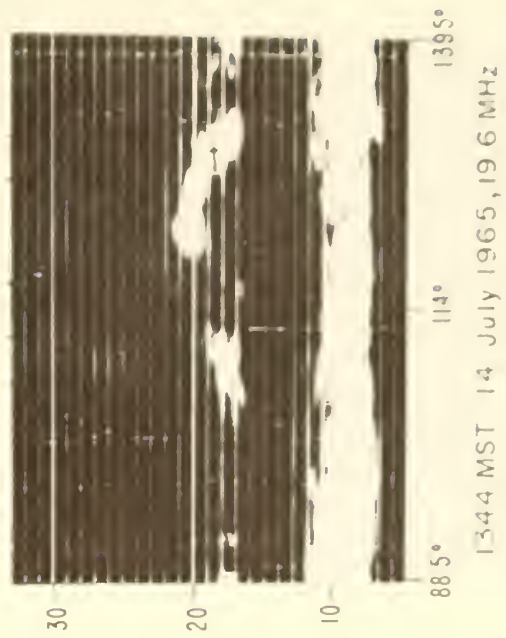
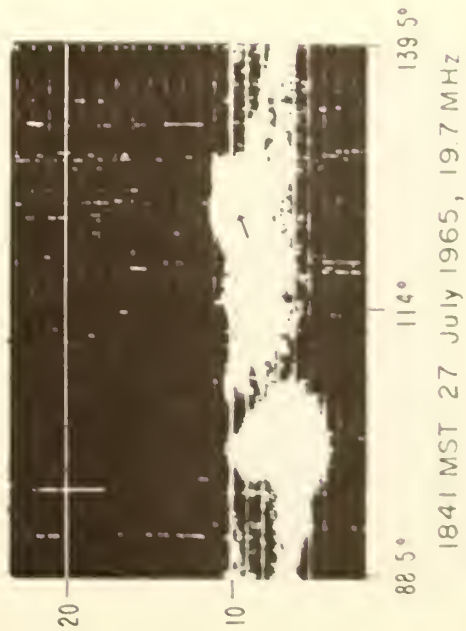
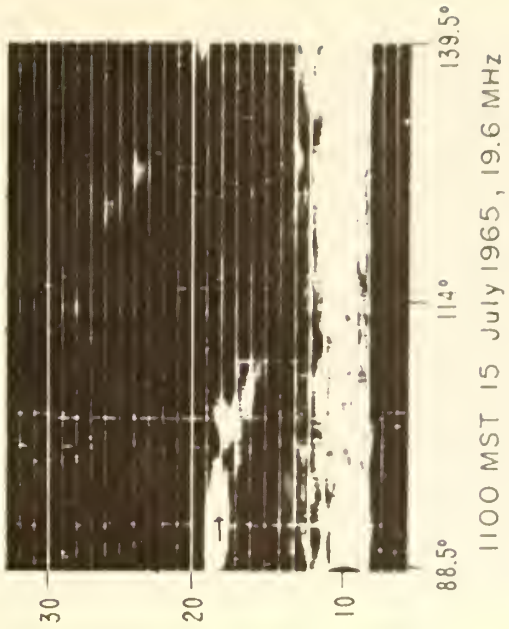
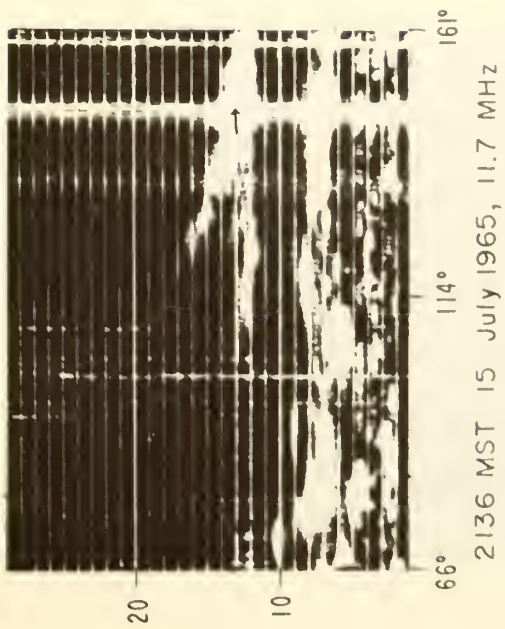


"Patches"

83795

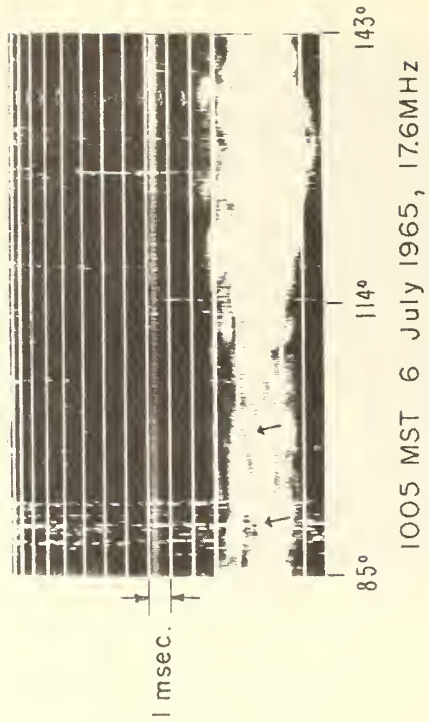
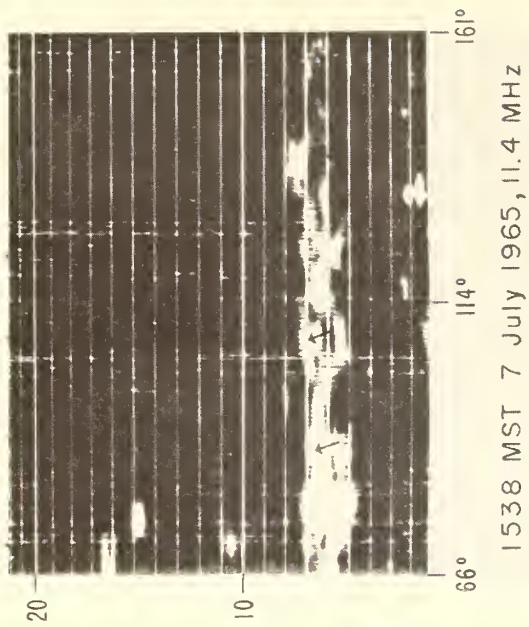
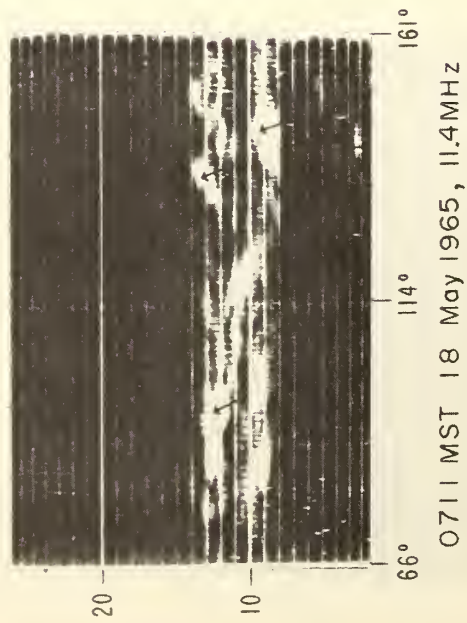
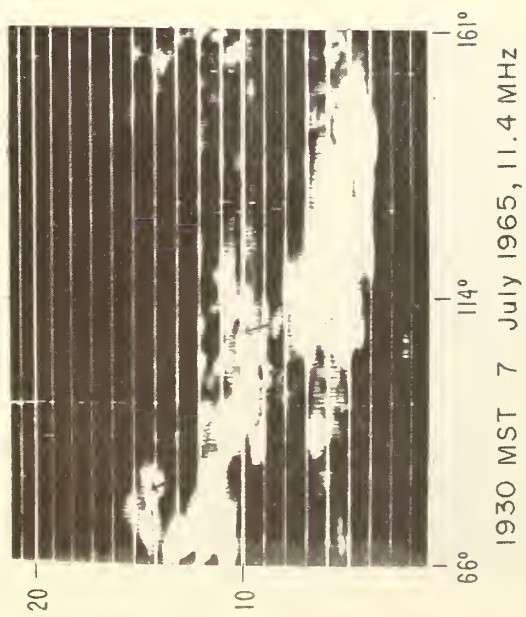


"Tilts"



"Large-Size-Blobs"

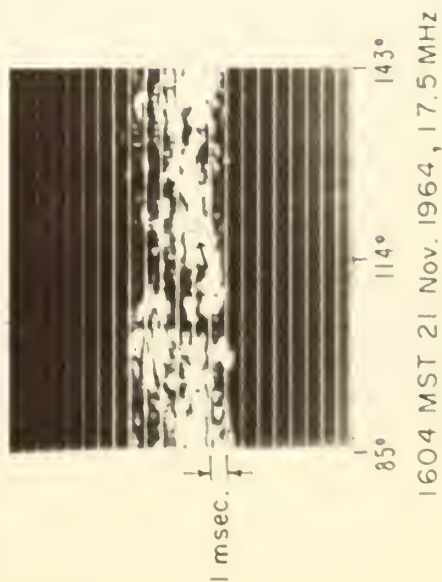
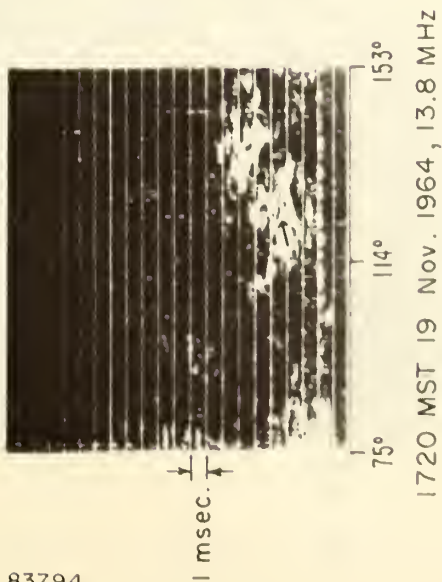




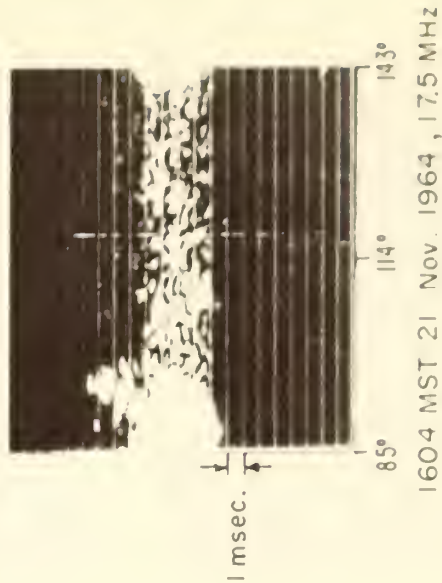
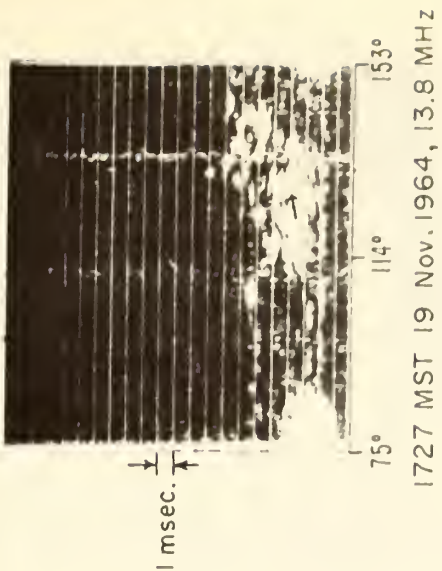
"Medium-Size-Blobs"

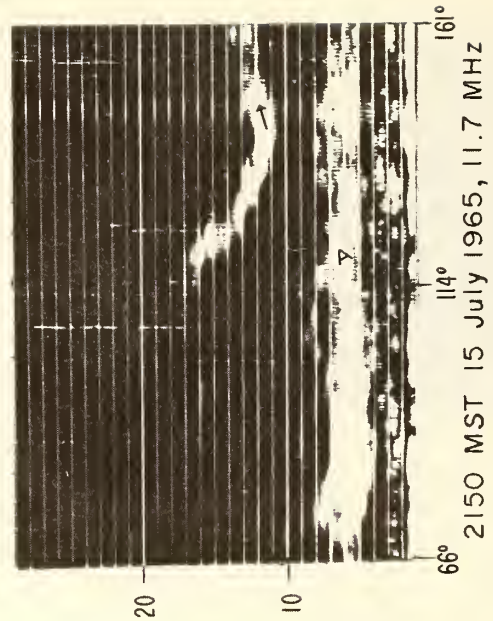
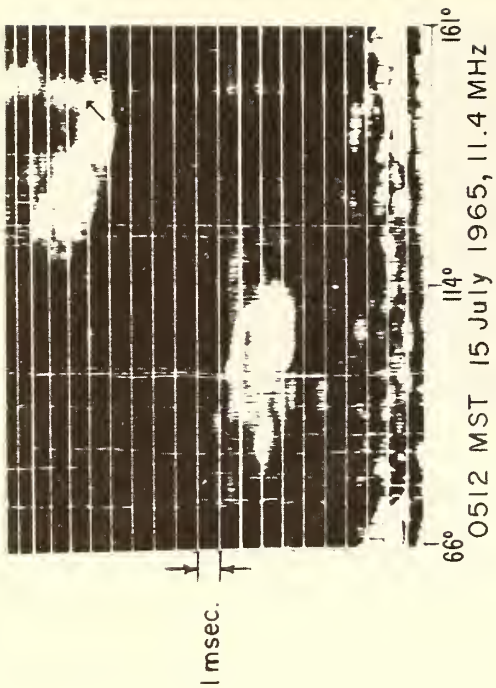
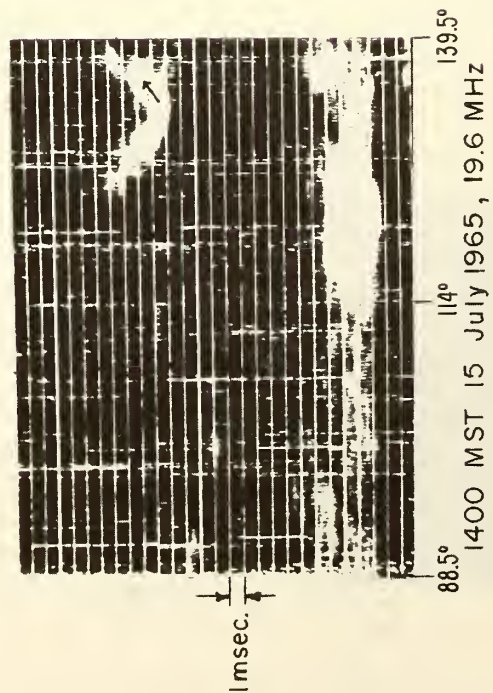
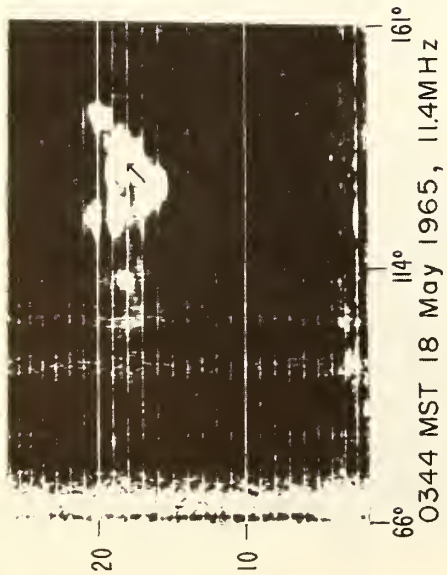


83794

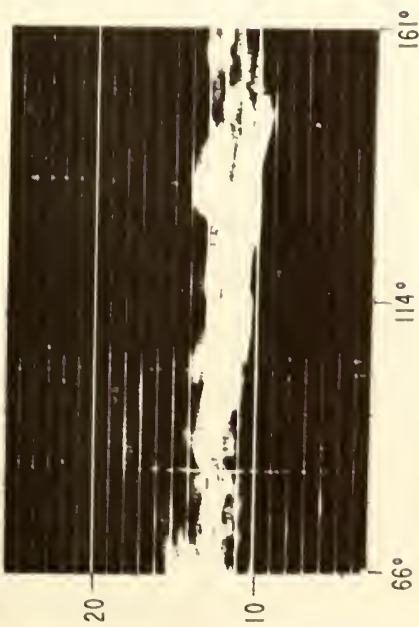


"Fine-Structure"

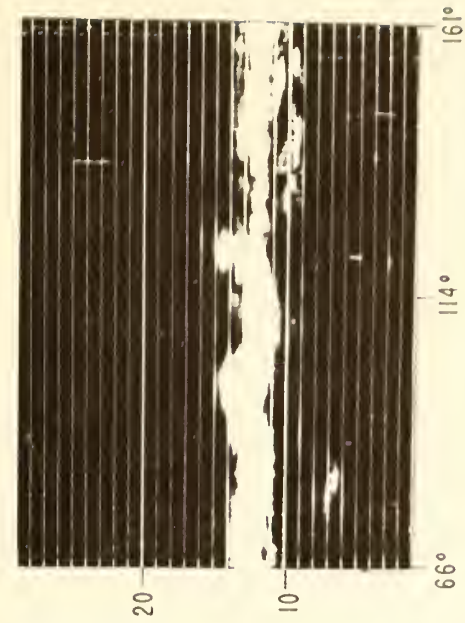




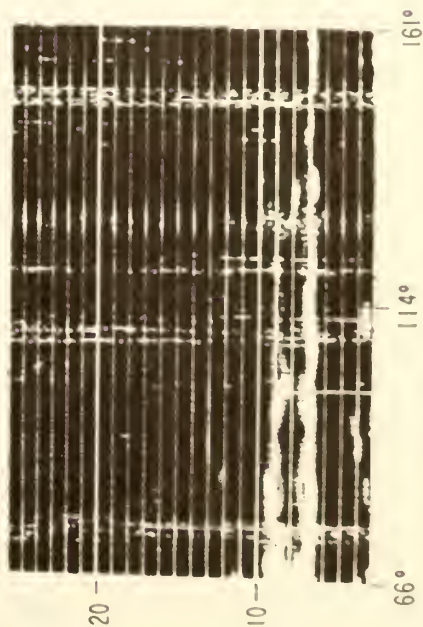
"Hook"



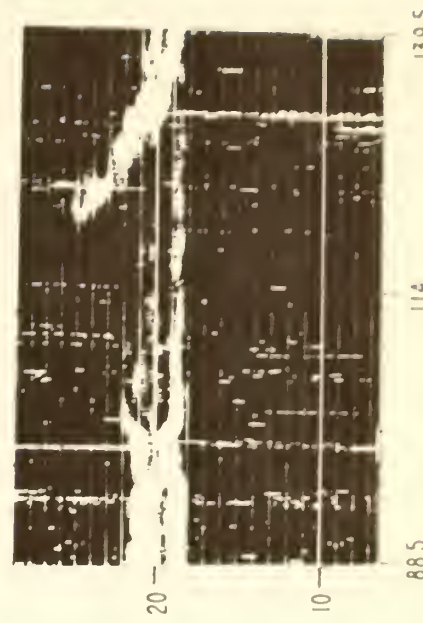
2027 MST 28 July 1965, 11.4 MHz



2008 MST 15 July 1965, 11.7 MHz



1214 MST 29 July 1965, 11.4 MHz



1224 MST 27 July 1965, 19.7 MHz

"Unclassified Echoes"





#### 4. RANGE - TIME BACKSCATTER

The data in the first part of this section were provided by Professor I. Ranzi of Centro Radioelettrico Sperimentale "G. Marconi", in Rome, who has also furnished the following information on the observing station:

Latitude and longitude: 42.02° N; 11.84° E  
Peak pulse power: 2.5 kW  
Pulse repetition frequency: 16.66 pulses/sec  
Pulse duration: 400  $\mu$  sec  
Type of antenna: Four-element horizontal Yagi; gain = 7 dB, beamwidth (-3 dB) = 56°, front-to-back gain ratio = 33 dB, height above the sea = 15 m (the antenna tower is on the coast, and all the first Fresnel zone of the reflected ray is on the sea for direction NNW.)

On each of the records, time (15° east meridian time) increases from left to right, and slant range (in kilometers) increases from bottom to top. The operating frequency for all the data is 18.6 MHz, and the antenna azimuth is indicated on the left end of each film strip. Photographic negatives of each of the pages are on file at the ESSA Laboratories photographic laboratory.

The high resolution data photographs on pages 53-62 were obtained by the CRPL<sup>1</sup> backscatter project group (R. Silberstein, W.L. Hartsfield and L. H. Tveten). These data were acquired during the period 1953-1954 with an oblique backscatter sounder located at Sterling, Virginia (Tveten, 1961). The salient system parameters are:

Peak pulse power : 200 to 500 kW  
Pulse repetition frequency: 25 pulses/sec  
Pulse duration: 40  $\mu$  sec  
Frequency: 13.7 MHz  
Antenna: Two 3-element vertically polarized Yagis spaced  $\lambda/2$  apart with the center of the array  $\sim \frac{\lambda}{2}$  above ground.

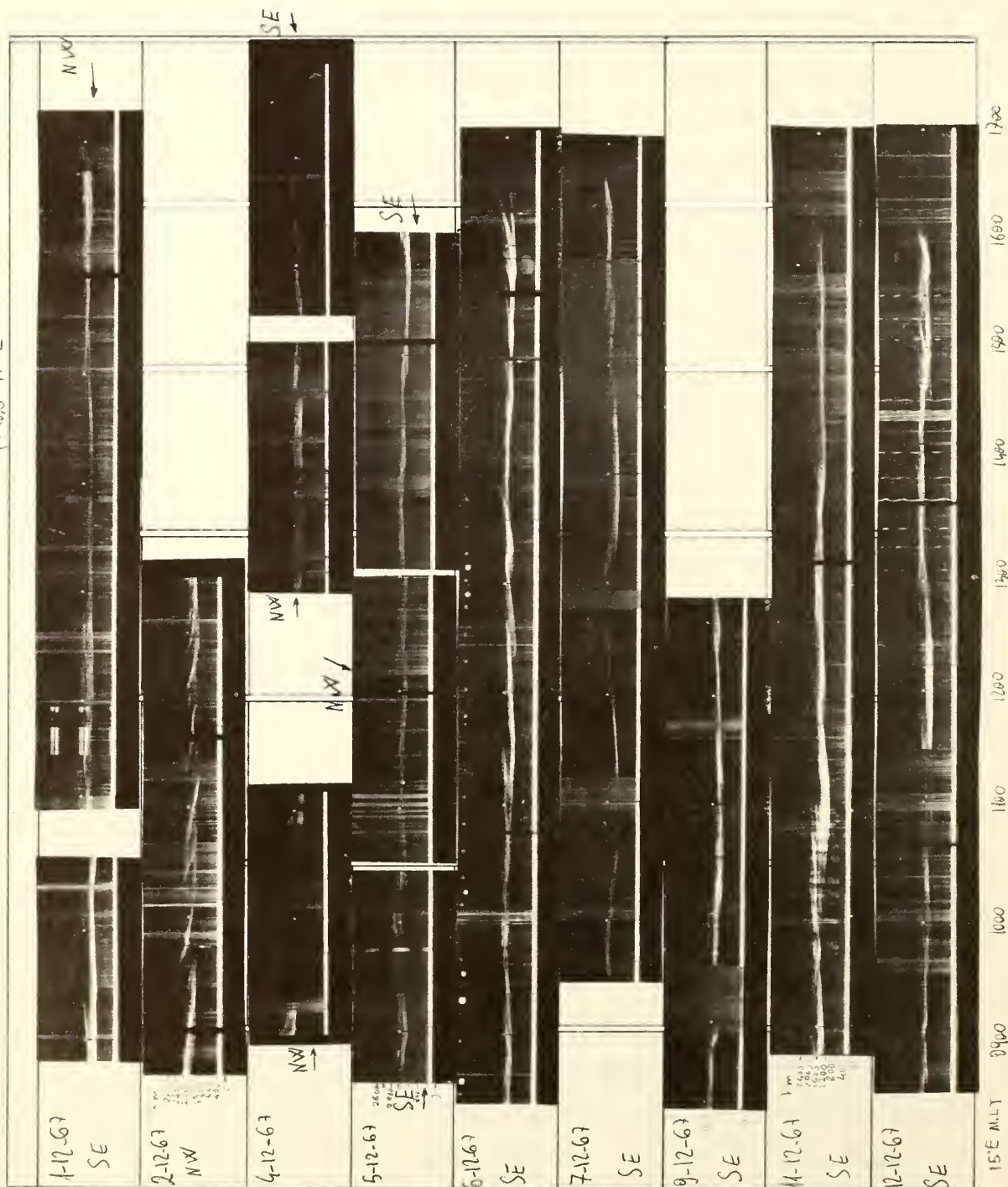
---

<sup>1</sup> Now the Institute for Telecommunication Sciences, ESSA.

CENTRO RADIOELETTICO SPERIMENTALE

G. MARCONI - ROMA

$f = 19,6 \text{ MHz}$



11

29-21-4

55

4-267

35

190-43

2

16-261

30

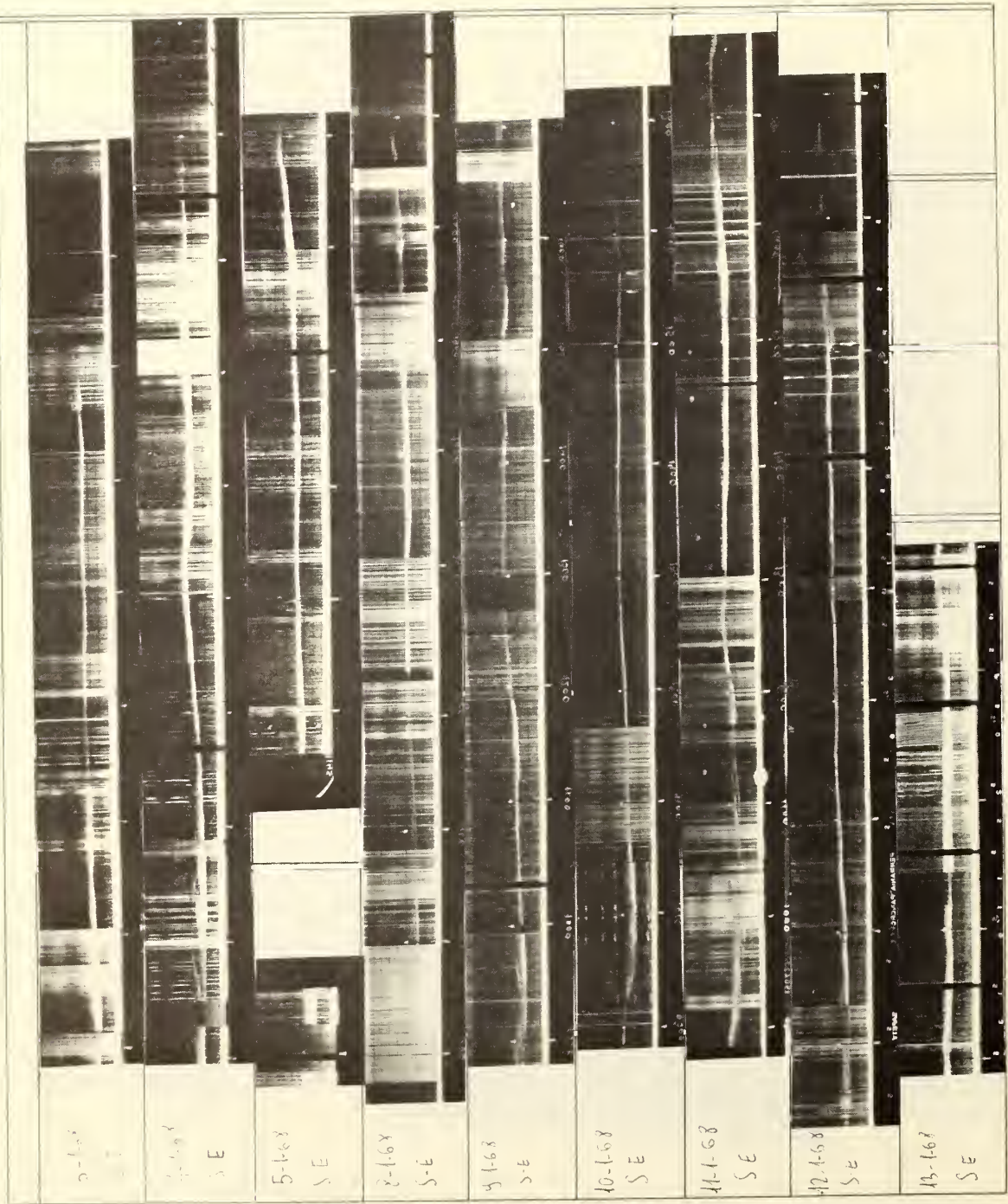
9.261

4



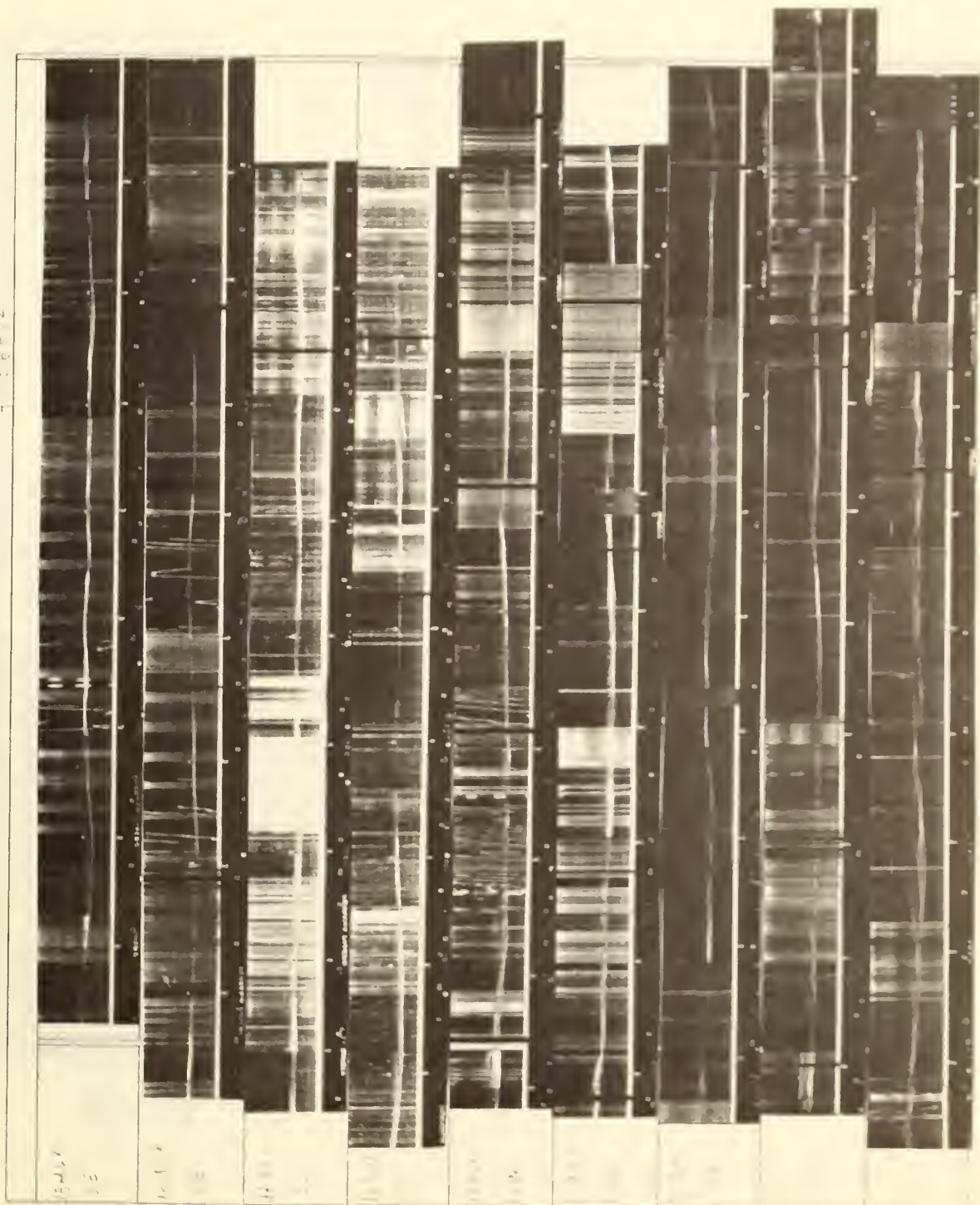
CENTRO RADIOELETTICO SPERIMENTALE  
G. MARCONI - ROMA

4 x 180 MHz



1400 1500 1600 1700 1800

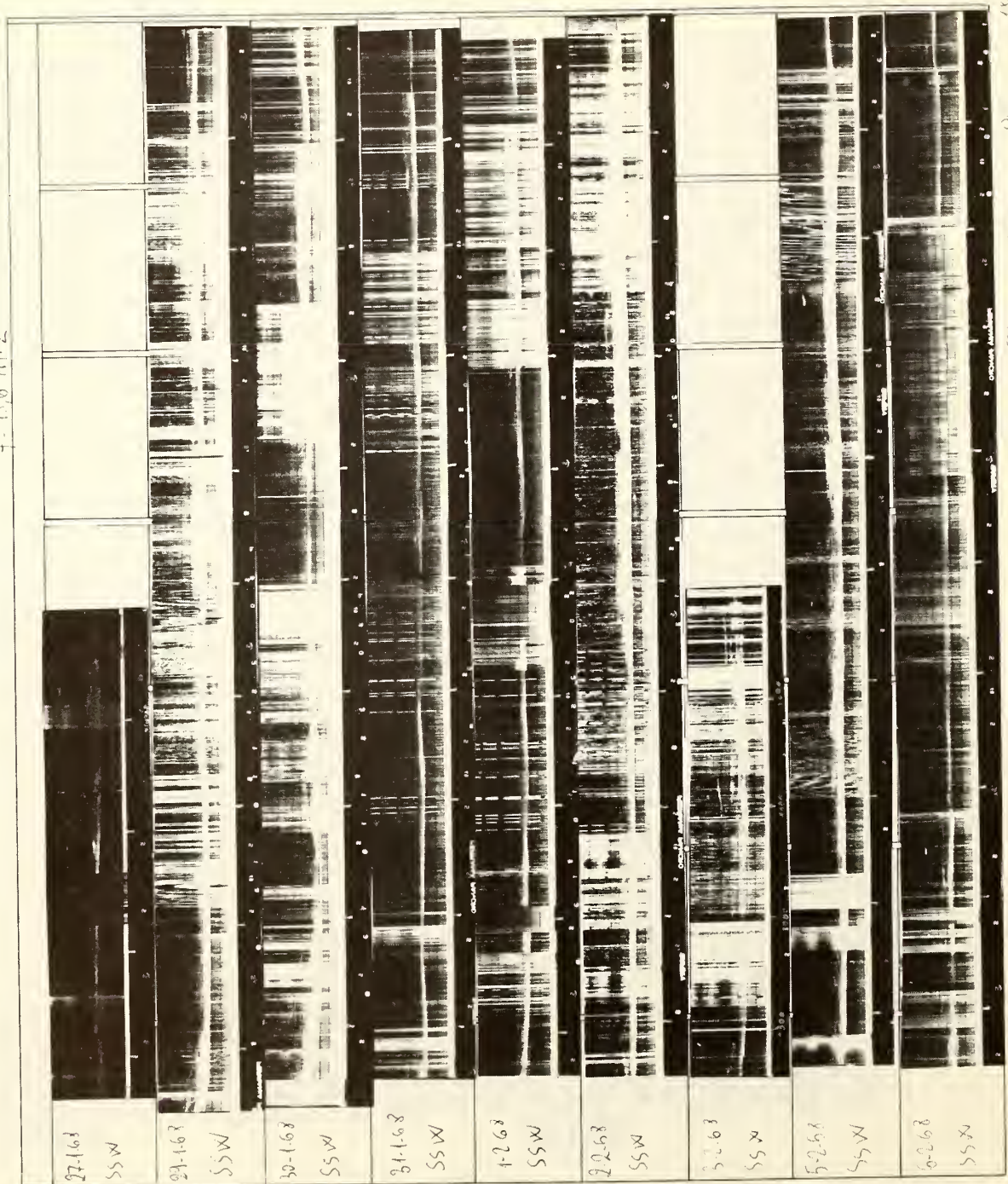




CENTRO RADIOELETTICO SPERIMENTALE

G. MARCONI - ROMA

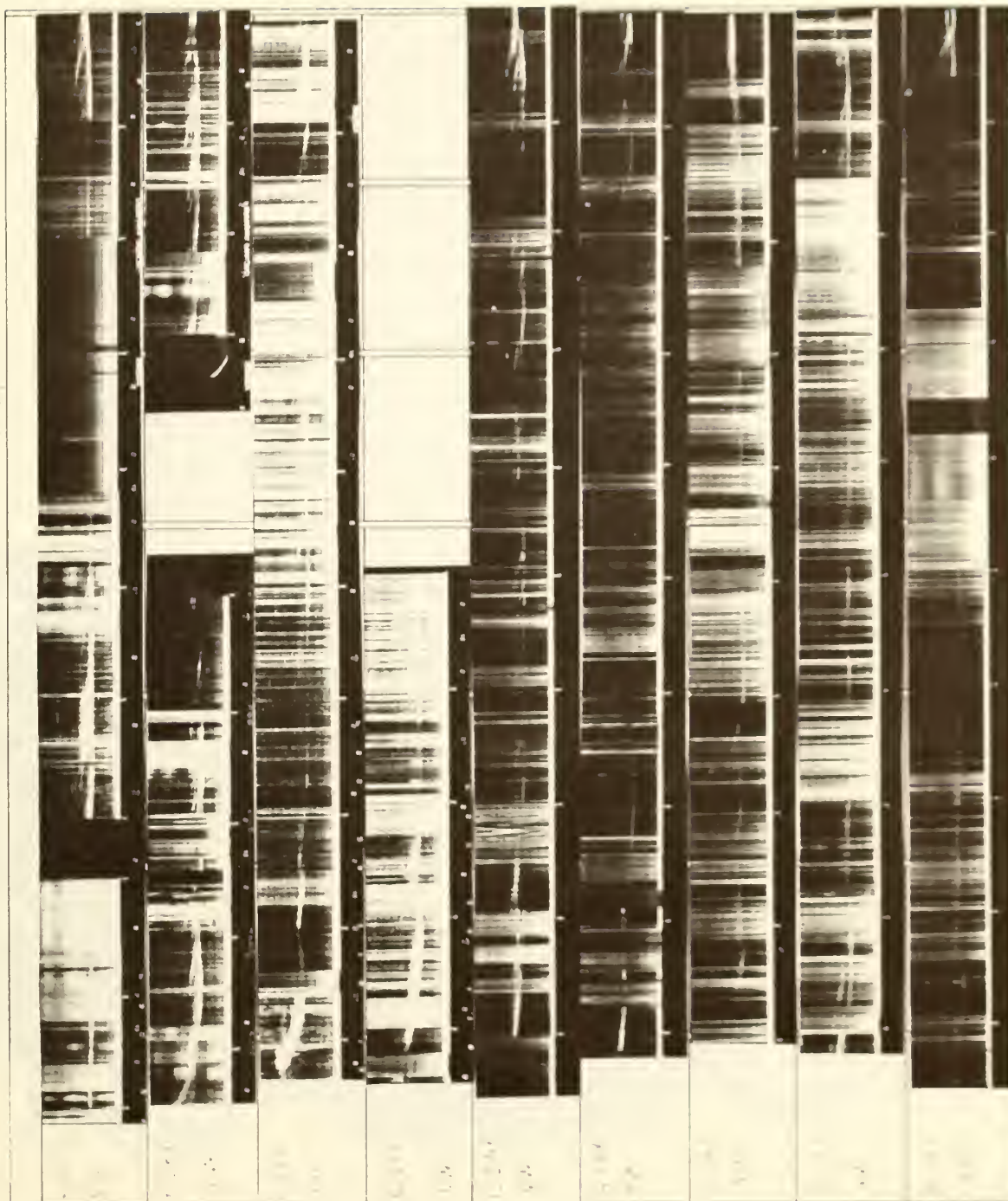
42.150 MHz

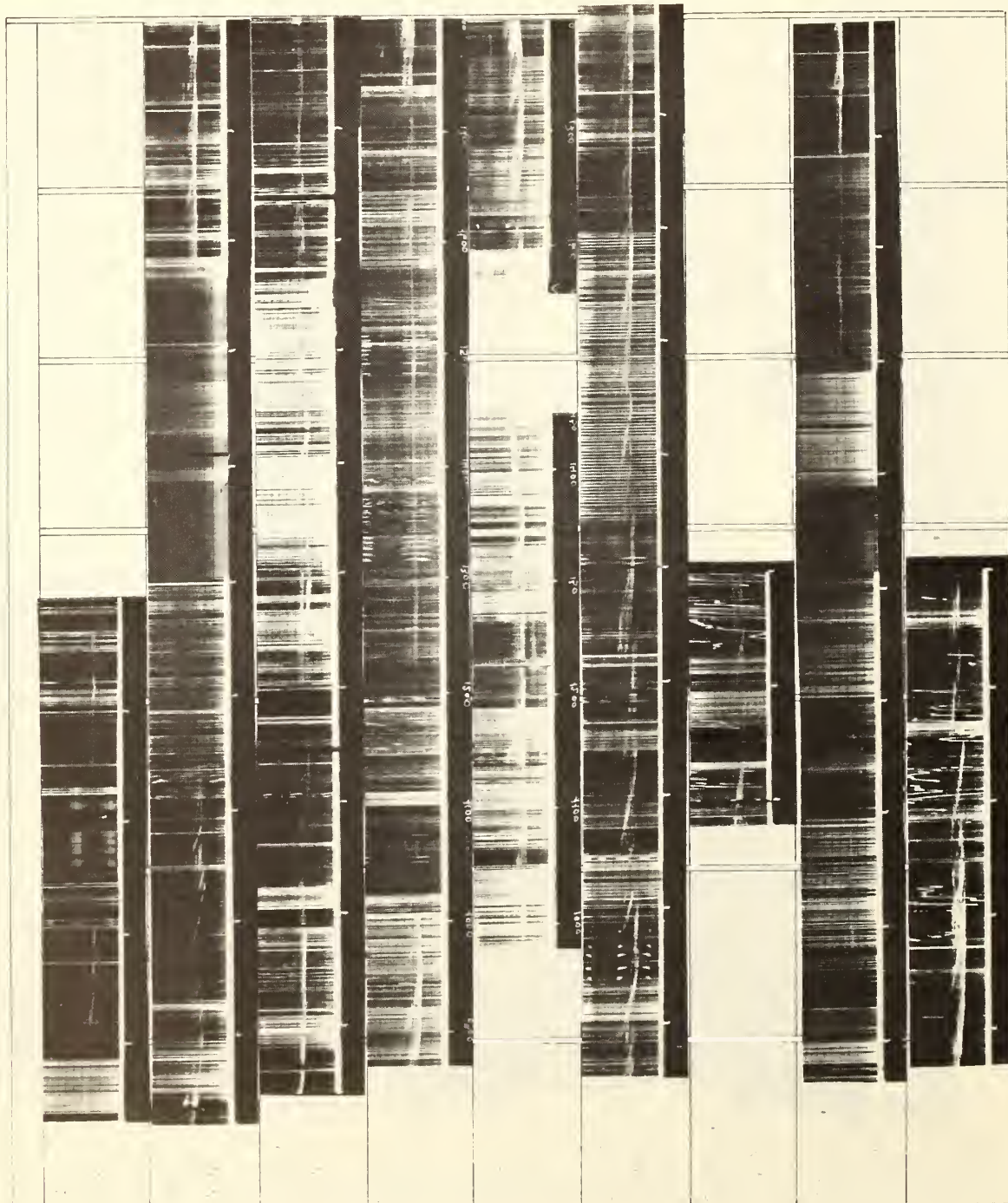




G. MARCONI - ROMA

25





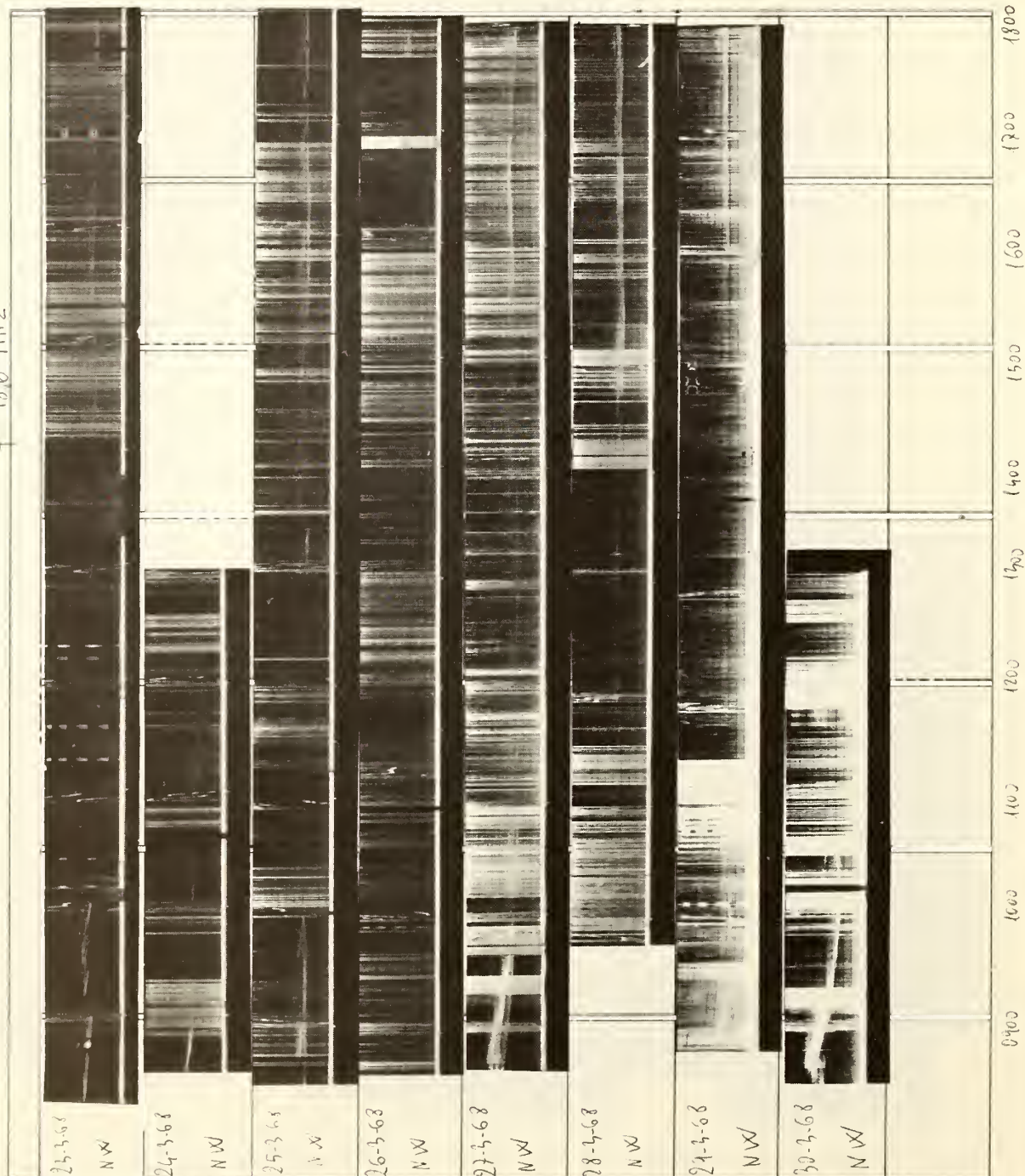


[illegible]

CENTRO RADIOELETTICO SPERIMENTALE

G. MARCONI - ROMA

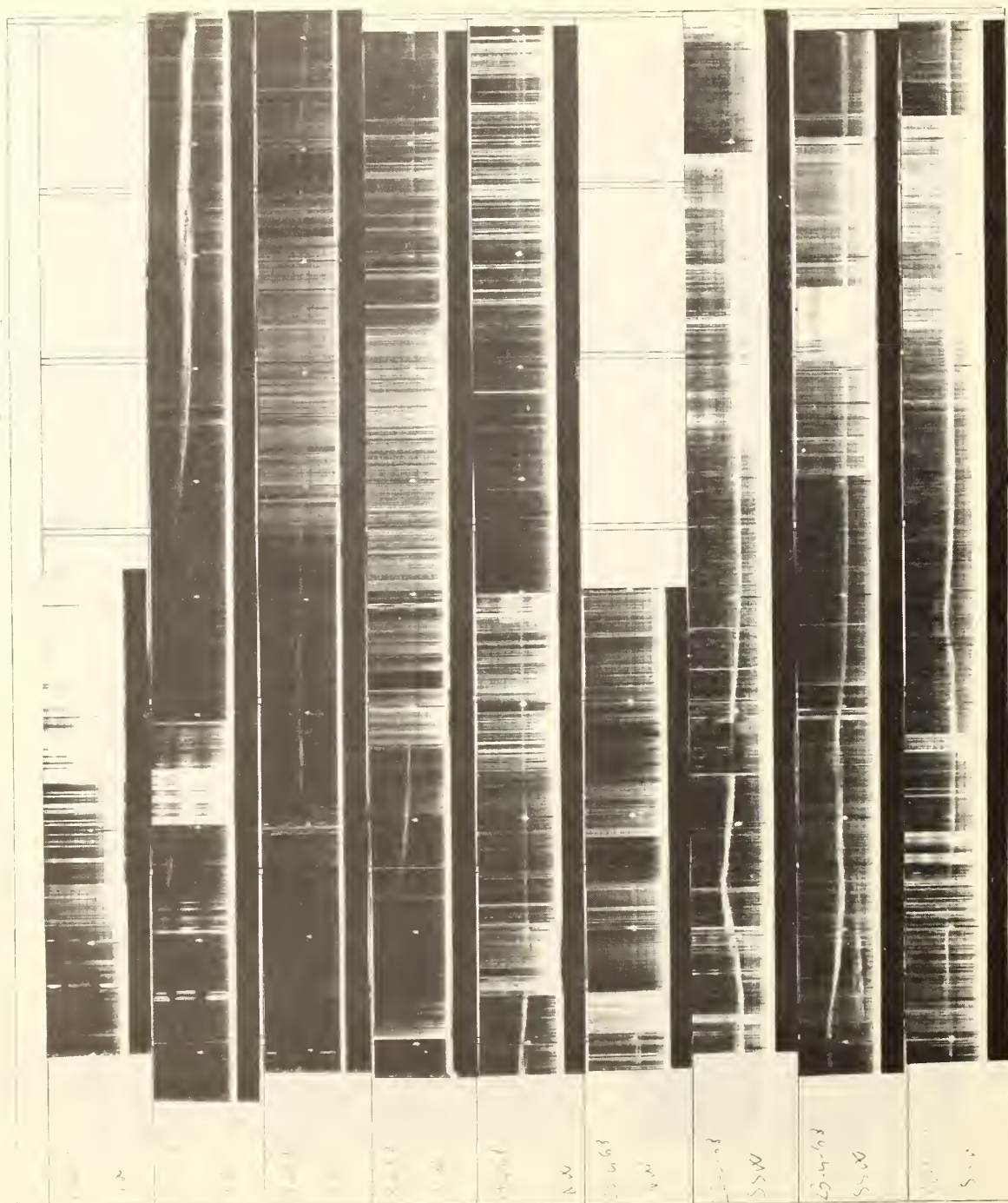
f - 186 MHz





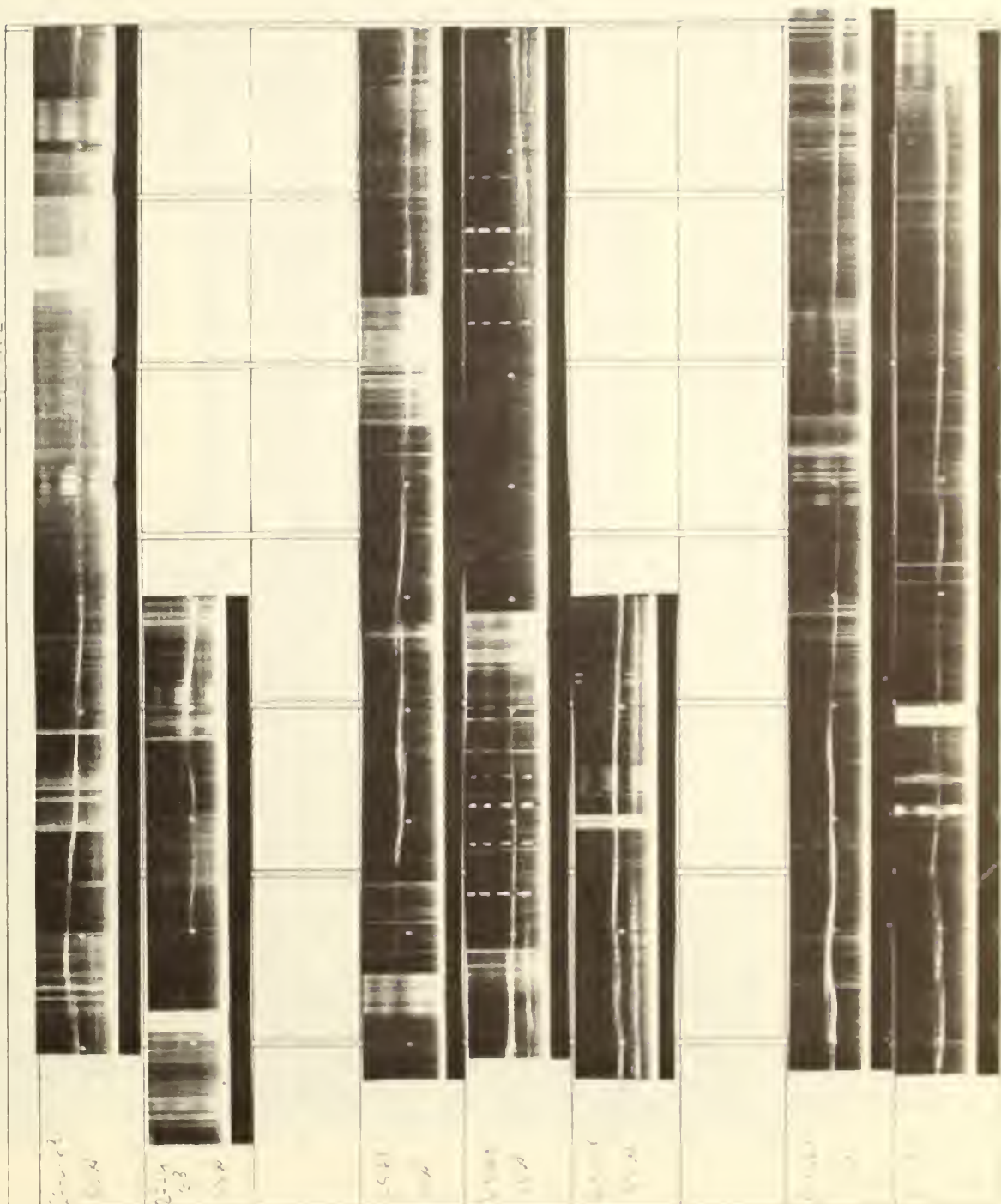
12.10.1912







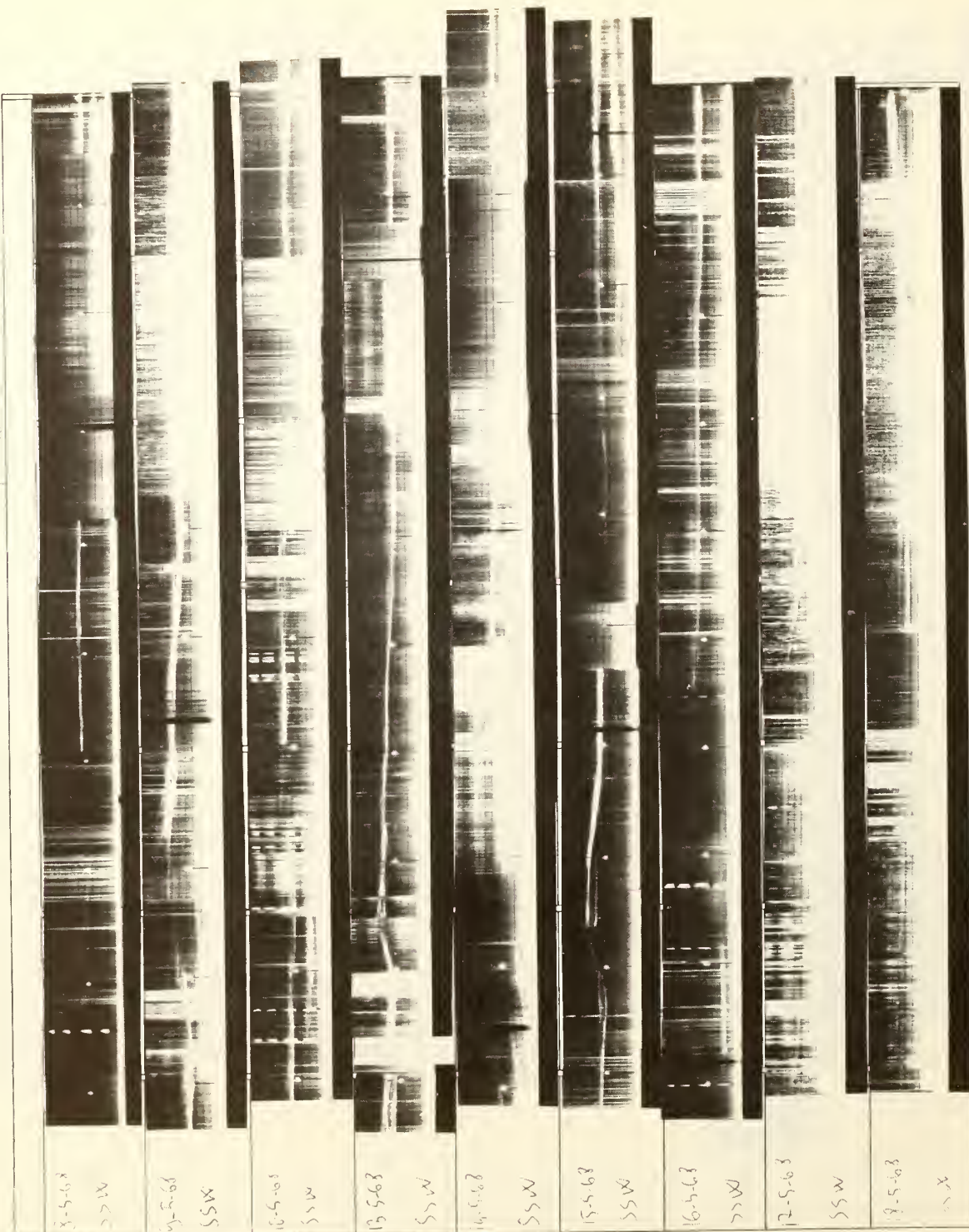
2100 MHz



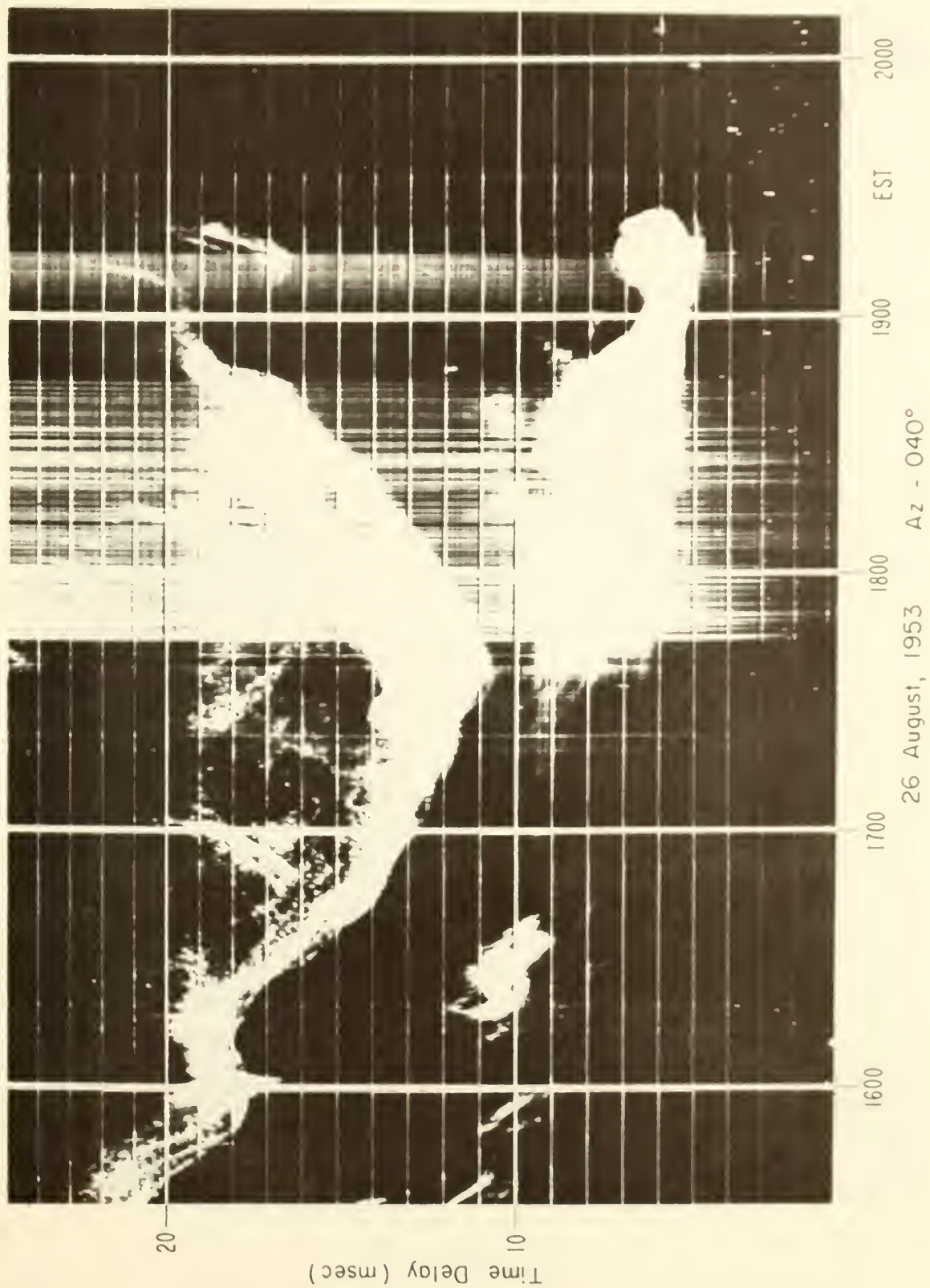
CENTRO RADIOELETTIRICO SPERIMENTALE

G. MARCONI - ROMA

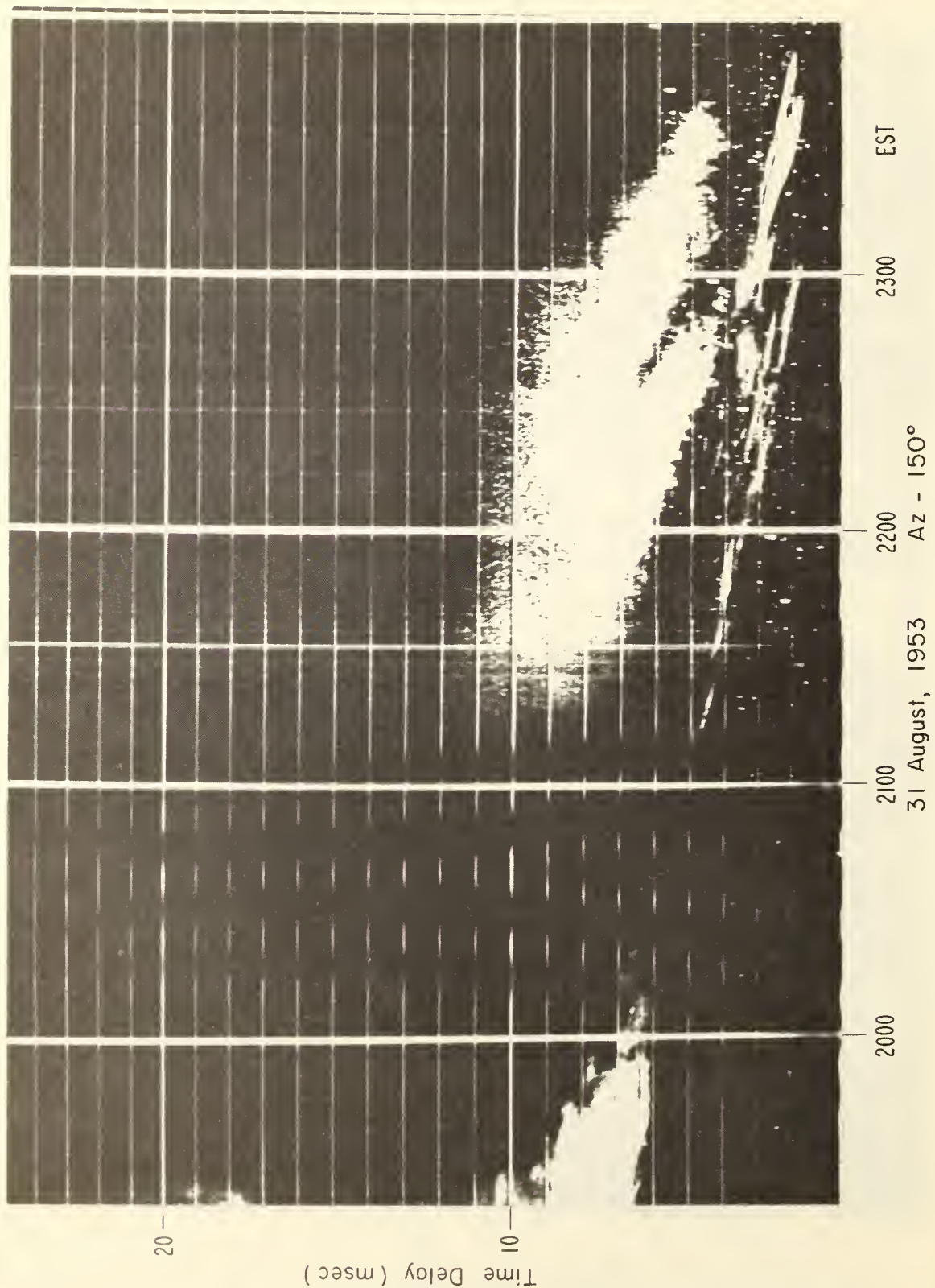
1 - 10.10.1922

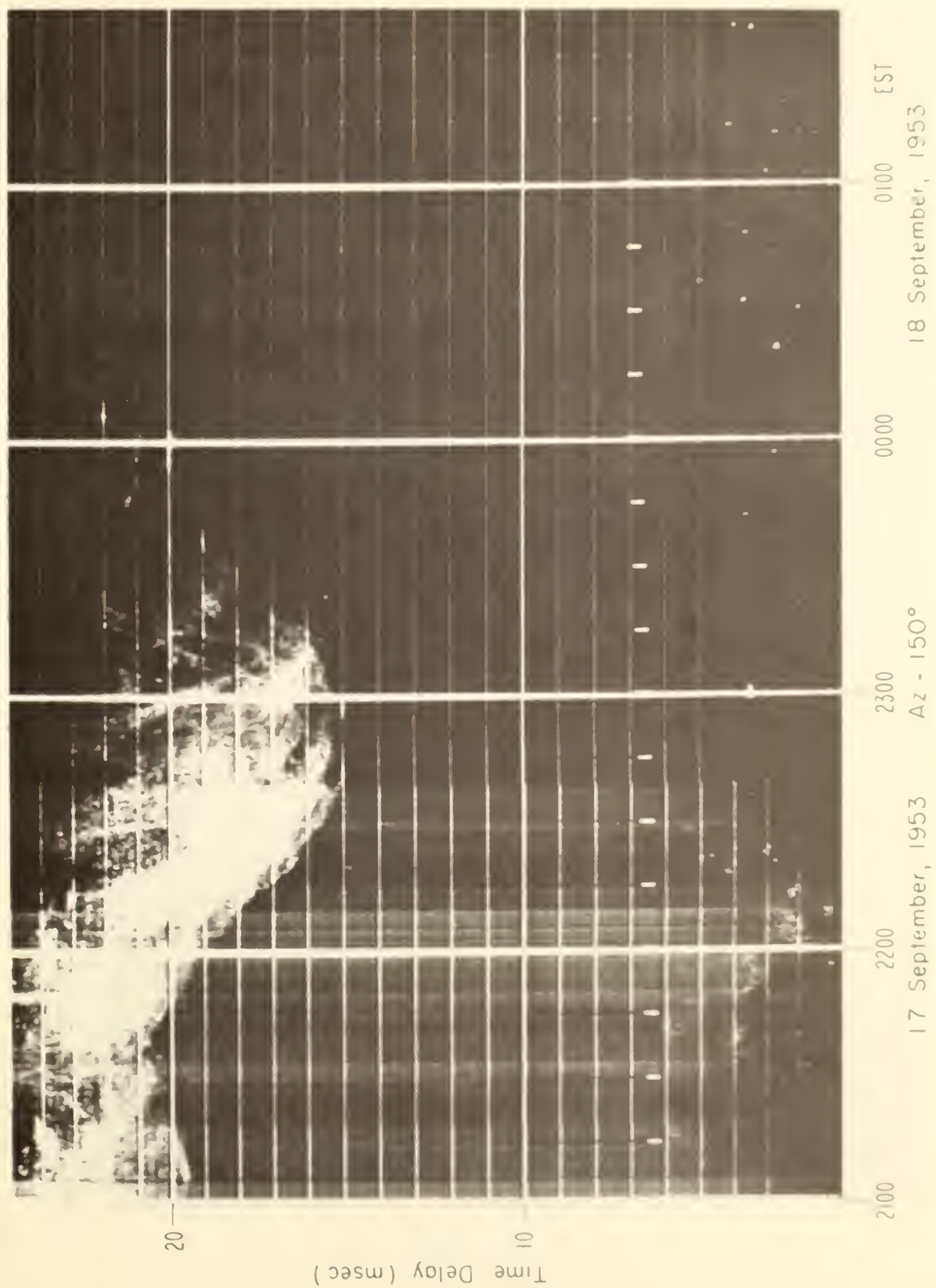




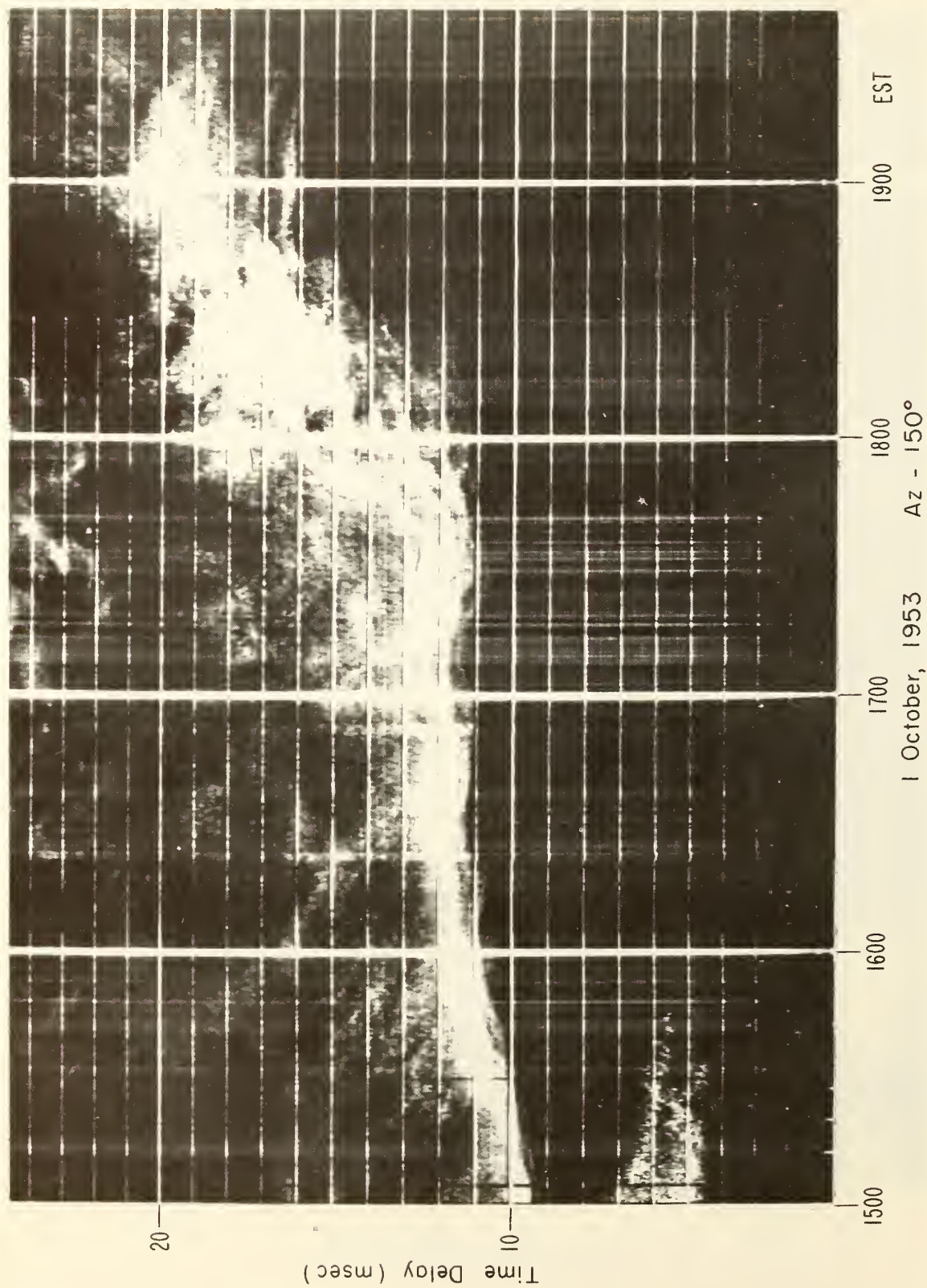




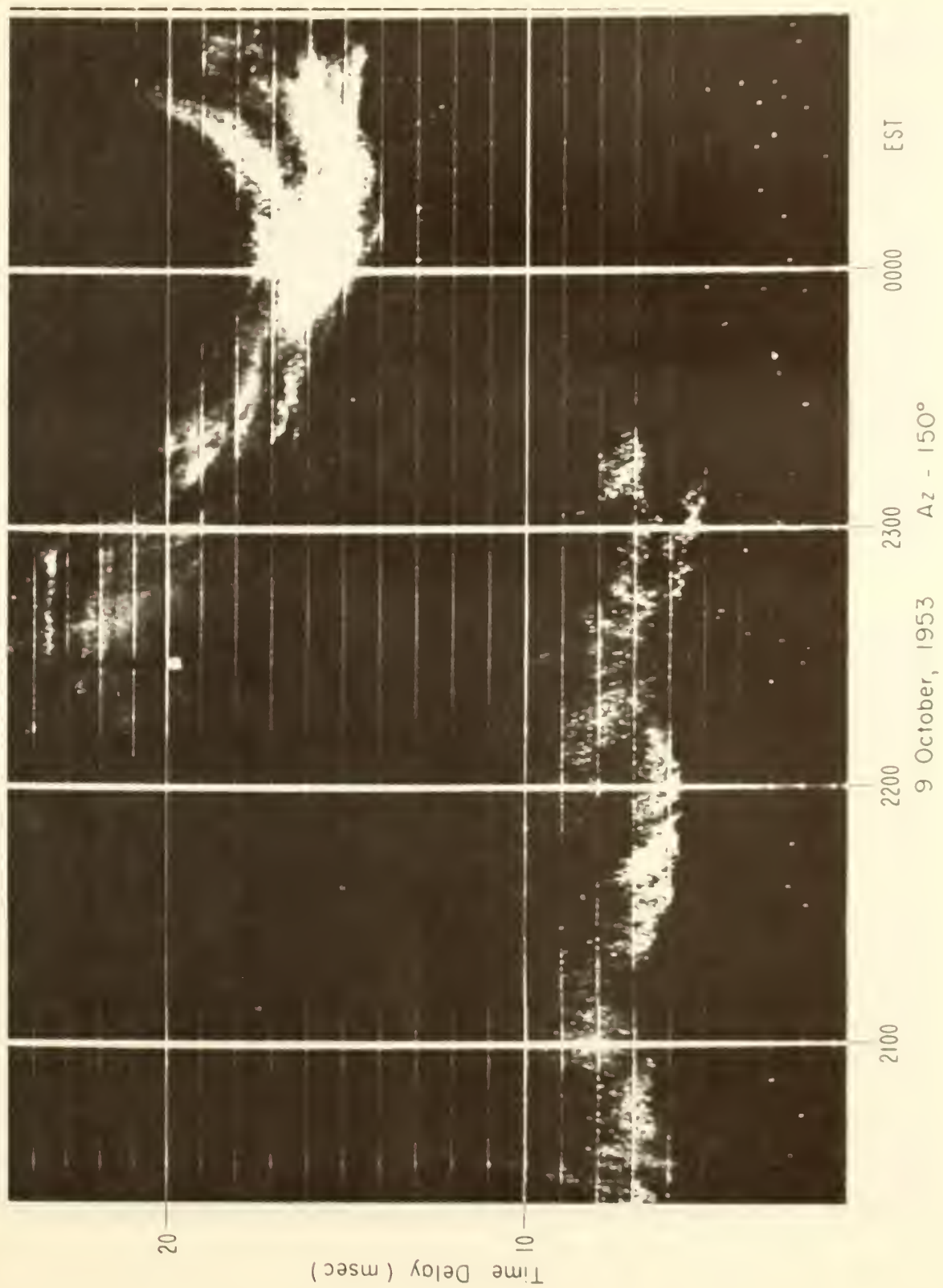


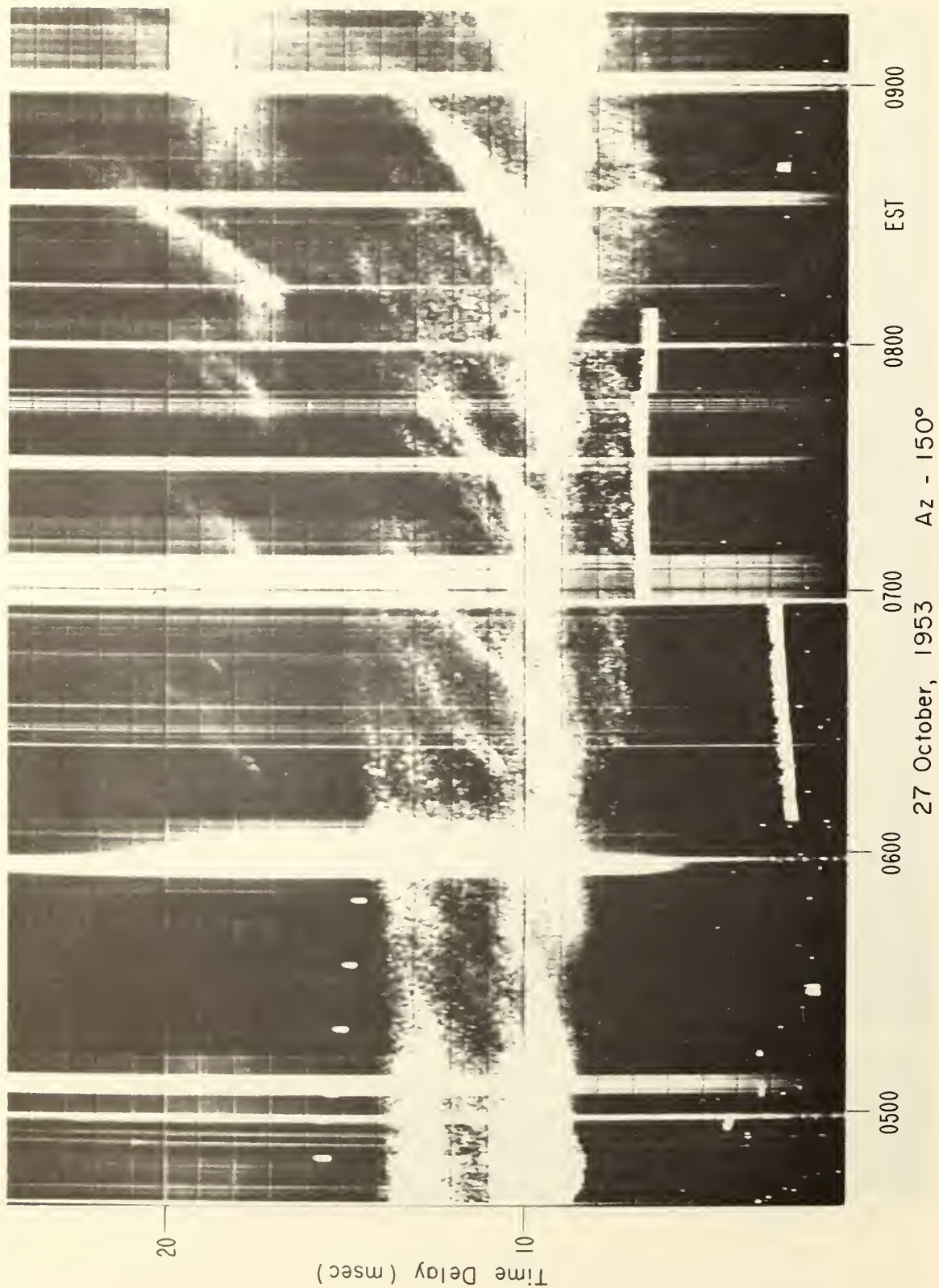


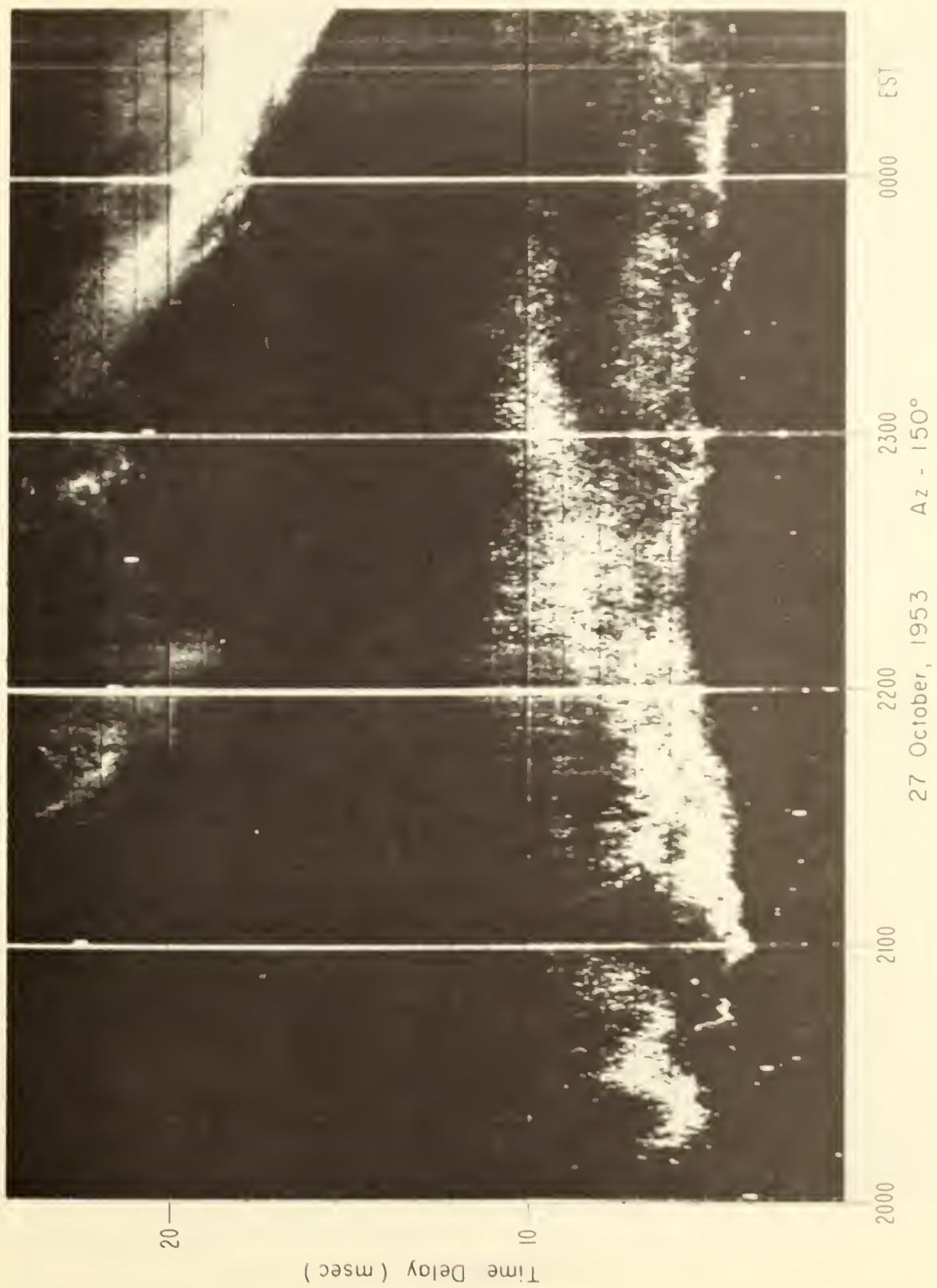




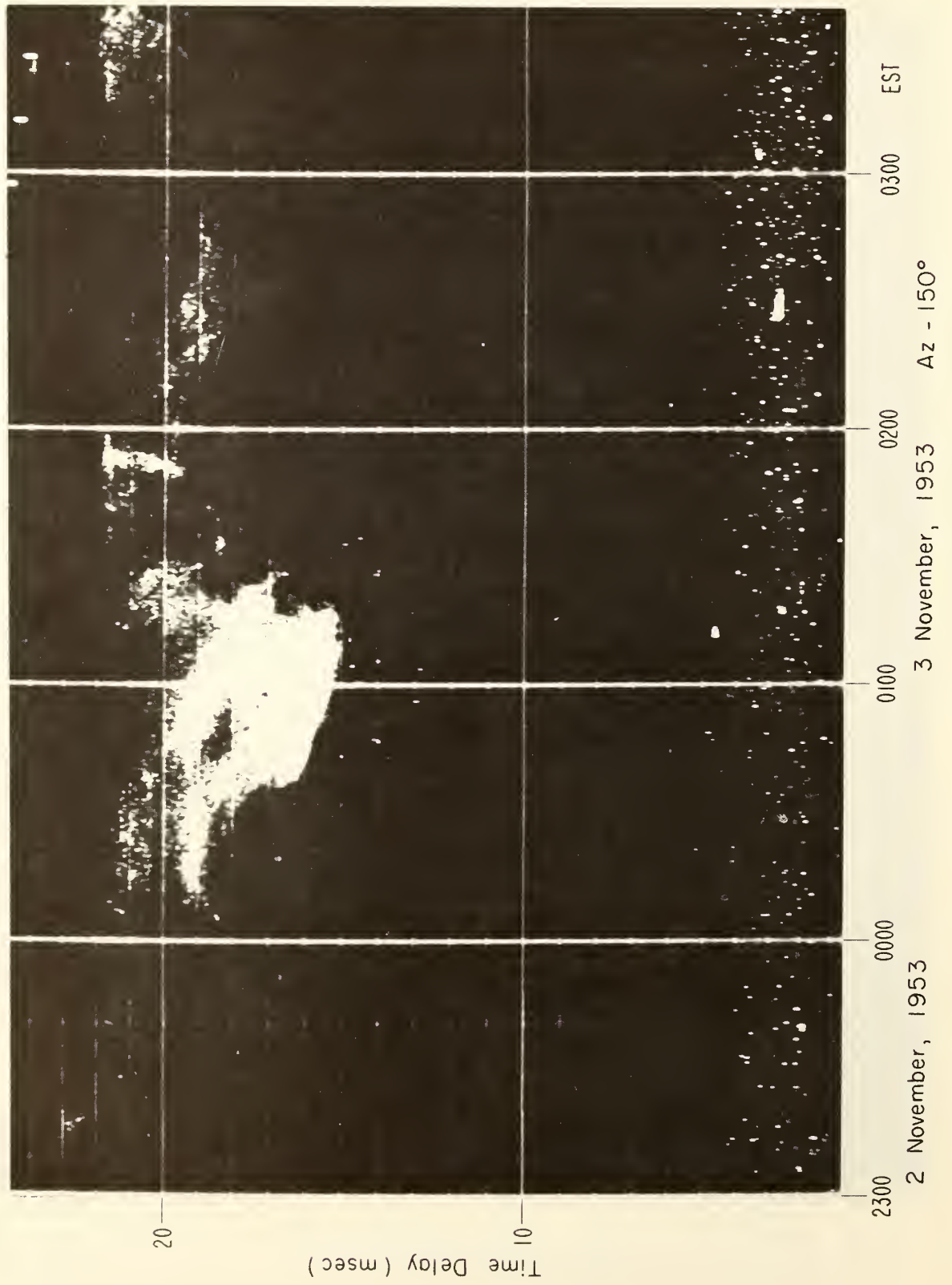


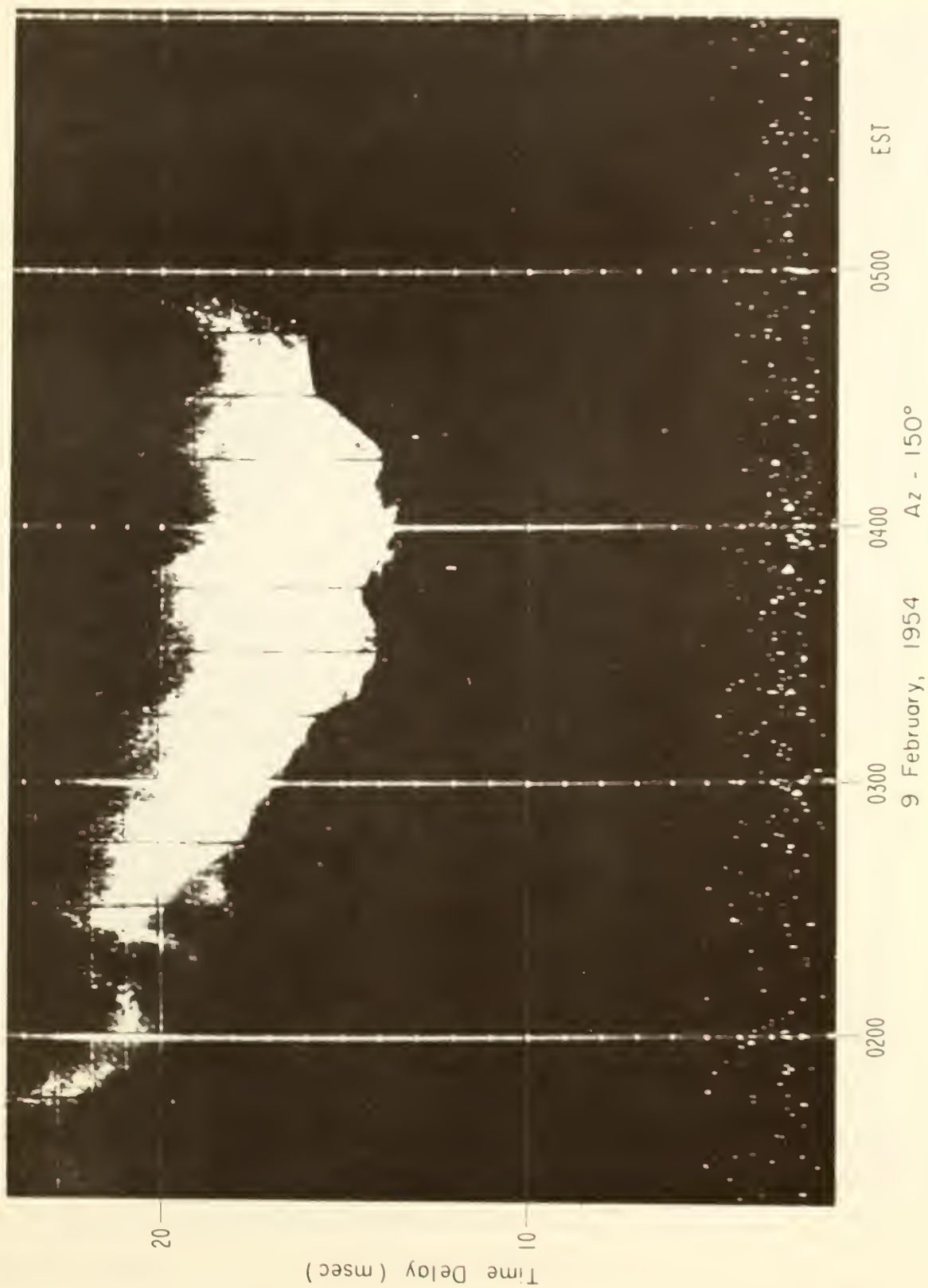
















## 5. SWEEP-FREQUENCY BACKSCATTER

These data were obtained at ESSA's Erie, Colorado, field site during January through April 1963 using two different antennas. Pertinent equipment parameters are shown on page 65, along with the sample data format. Pages 66-68 show soundings on the four cardinal geographic azimuths using the rotatable log-periodic antenna. Various "signatures" obtained at different azimuths during winter and equinoctial months of 1963 are shown on pages 69 through 83. The multiple traces on the left of most of the data photos in this section are multiple vertical incidence (V-I) echoes. The oblique backscatter echo is observed to take off from the second-order vertical trace as explained by Peterson (1951). The distorted nature of the V-I traces in the region of 1.0 - 6.5 MHz is due to the nature of the frequency-determining cam used in this particular sounder which resulted in transmission at a fixed frequency of 6.5 MHz in this section of the ionogram.

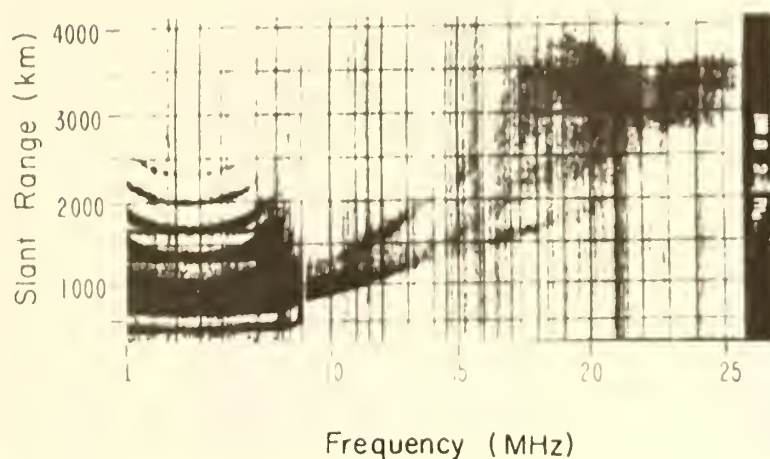
Pages 84-85 in this section display data obtained with the high-resolution system described in section 2. The "wide-beam" data were acquired using only one of the antennas of the 25-element horizontal array; the narrow-beam data were recorded using the entire array. These data are included to illustrate how a narrow antenna beam shows the ionospheric "fine-structure" at midlatitudes.

No attempt has been made to classify the echoes in this section as was done in section 2, since an excellent atlas of sweep-frequency backscatter data calibrated in amplitude has been compiled by Gilliland (1965).

A listing of available sweep-frequency backscatter data obtained at the Erie, Colorado, site is included in the appendix of this atlas following the listing of range-azimuth and range-elevation scan backscatter data.

The two records on page 86 of this section show examples of simultaneous oblique sweep-frequency backscatter, forward pulse propagation, and vertical incidence sounding data. The HF propagation path was from Sterling, Virginia to Boulder, Colorado (2370 km) and the experiment was described in detail by Silberstein (1958). Page 120 in the appendix lists the 35-mm film data on hand at Boulder from this experiment.

# SWEEP-FREQUENCY DATA FORMAT



Location - Boulder, Colorado

Time - Mountain Standard Time (MST)

Output Power  $\approx$  50 kw

Pulse Repetition Frequency = 12.5 Pulses/Second

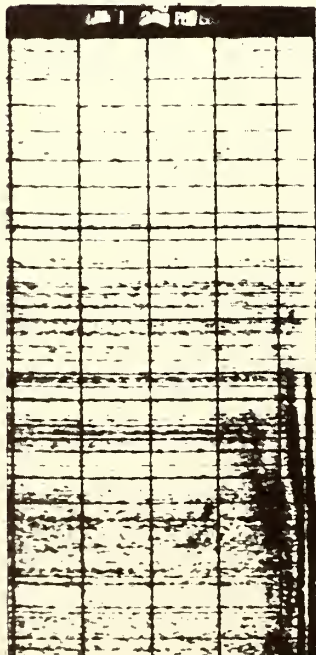
Pulse Length = 250  $\mu$ sec

Antennas : a.) Rhombic Directed Toward  $114^\circ$  } RHA  
Geographic Azimuth

b.) Rotatable Log-Periodic — LPA

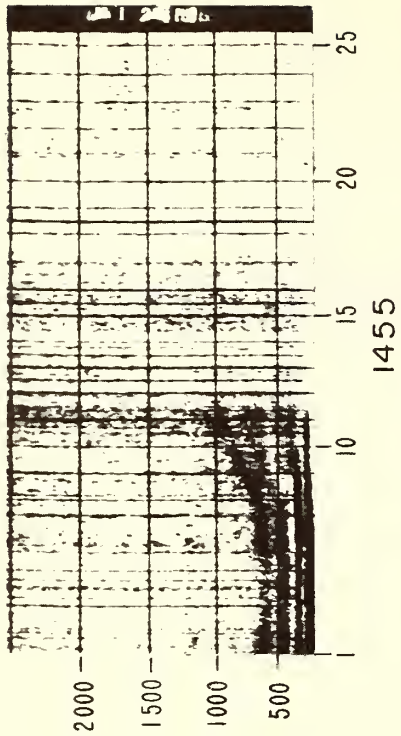


NORTH

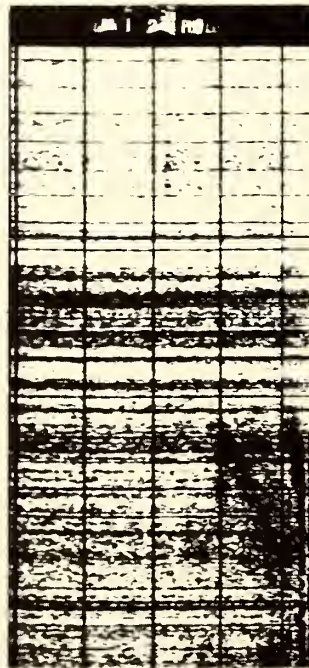


1448

SOUTH



EAST



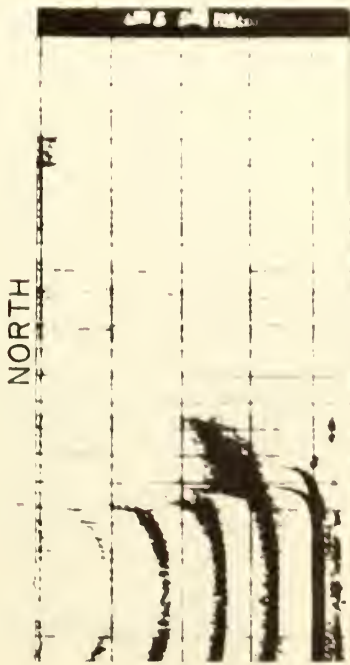
1145

WEST

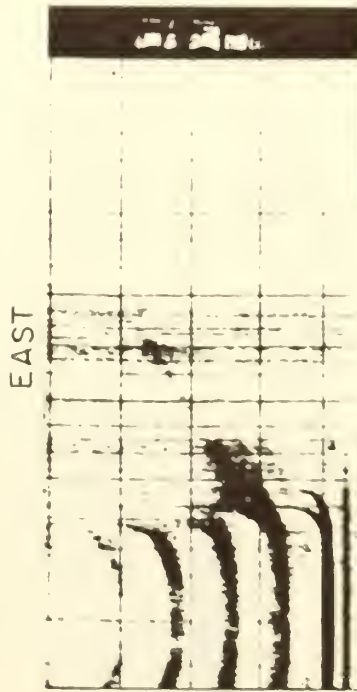
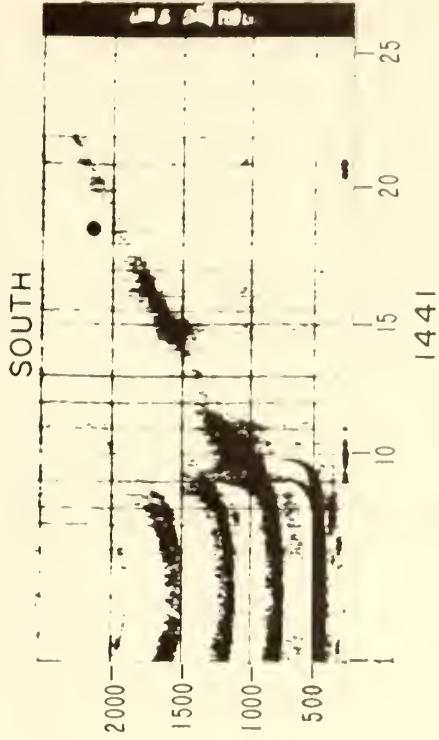


1457

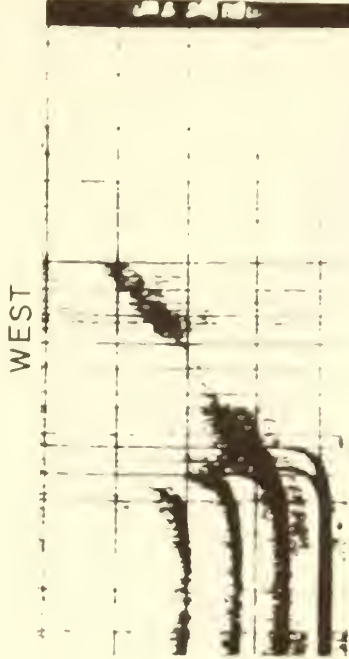
LPA 1 January 1963



1425



1437

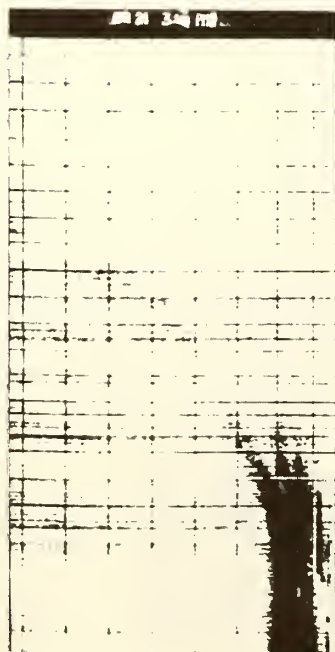


1446

LPA 6 January 1963

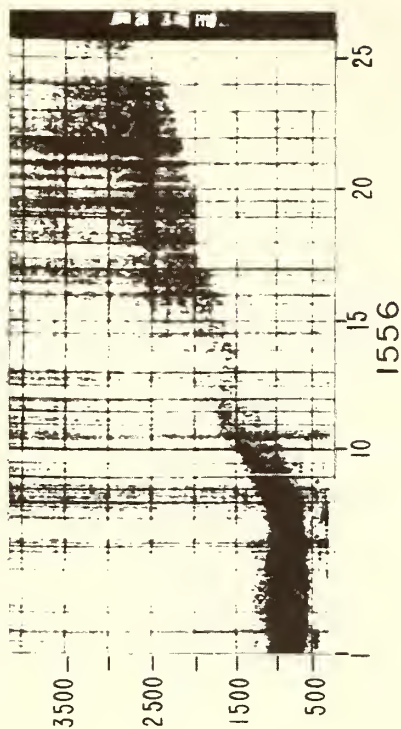
85173

NORTH

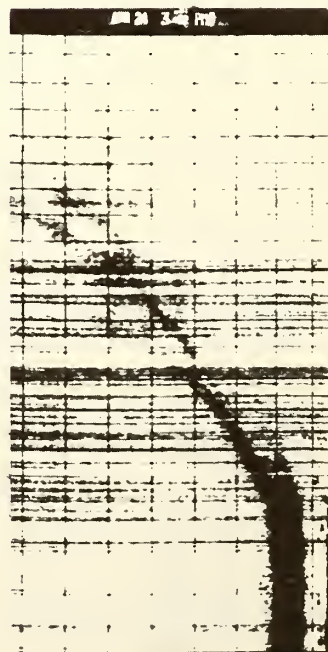


1548

SOUTH

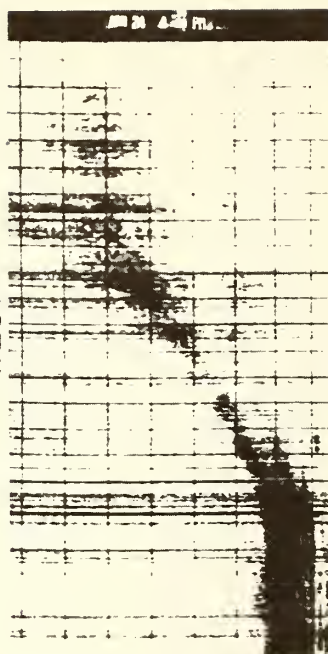


EAST



1552

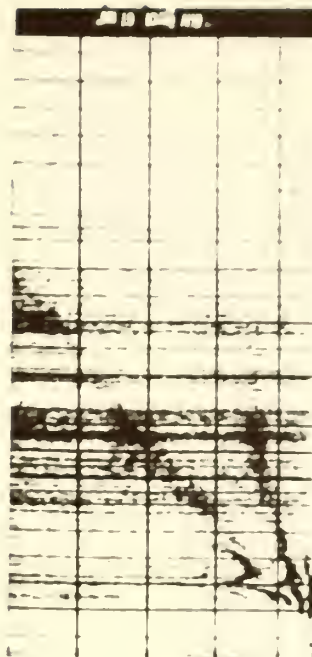
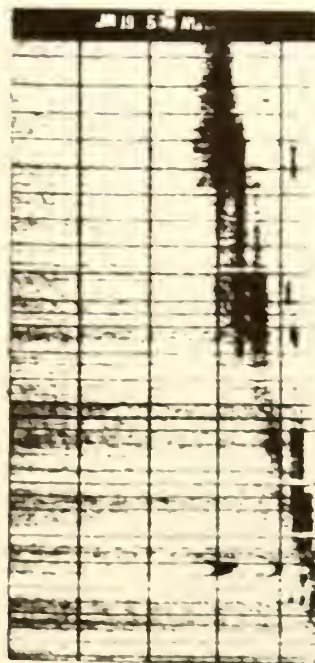
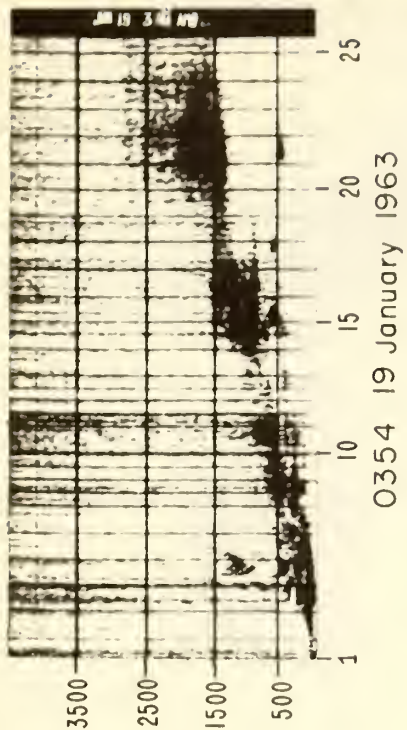
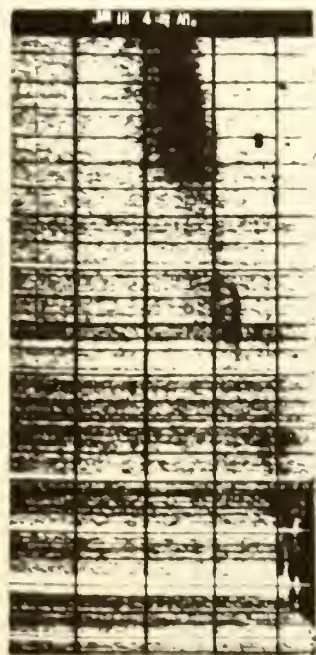
WEST



1600

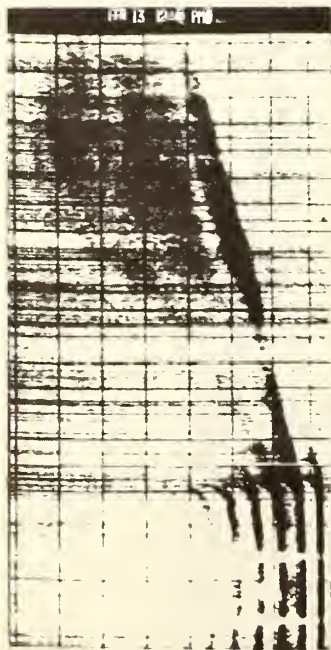
LPA 24 April 1963



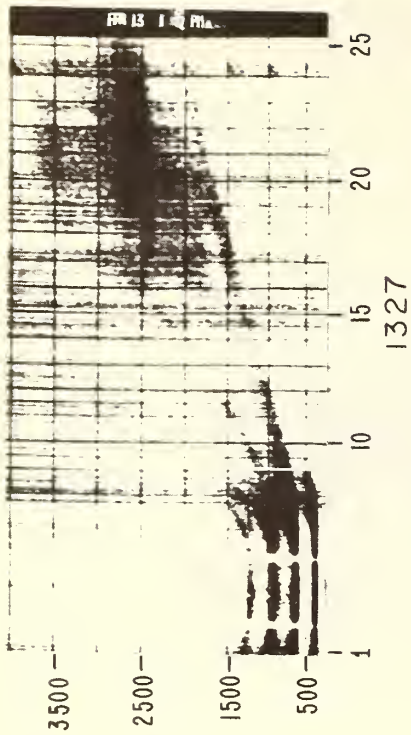


L P A → 150°

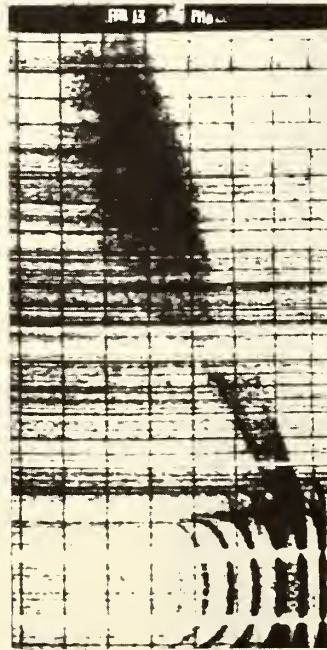
85163



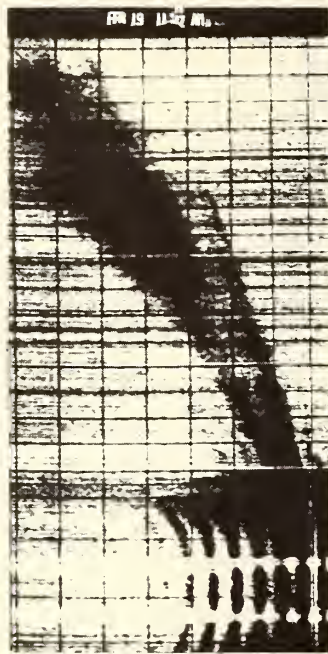
1240



LPA → 150° 13 February 1963



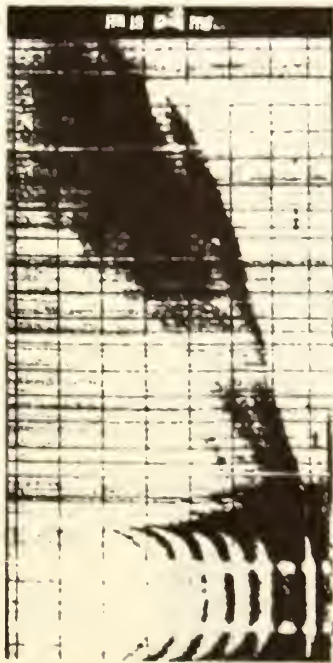
1425 13 February



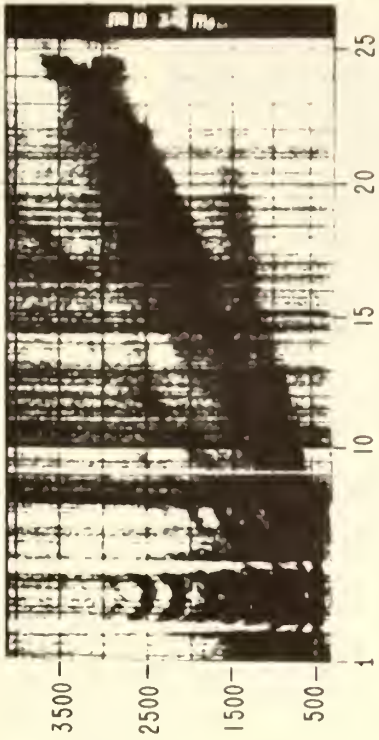
1117 19 February

LPA → 150°



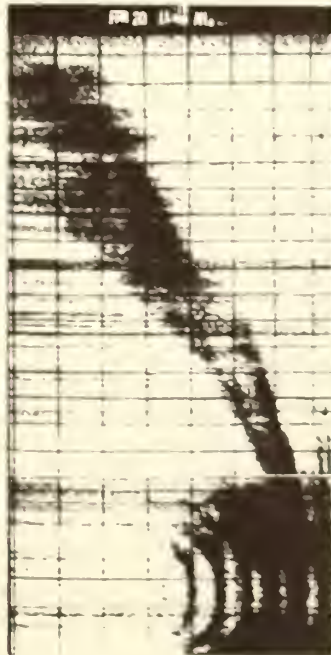


1236

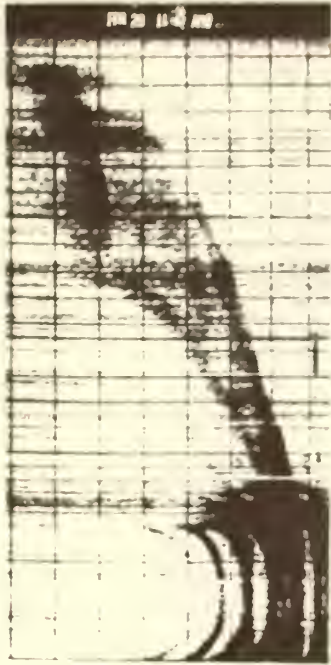


1529

19 February 1963



1119



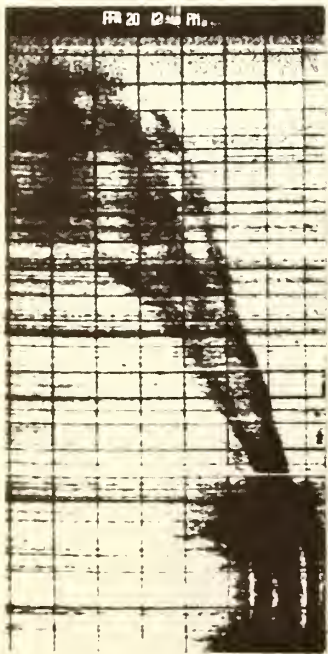
1157

20 February

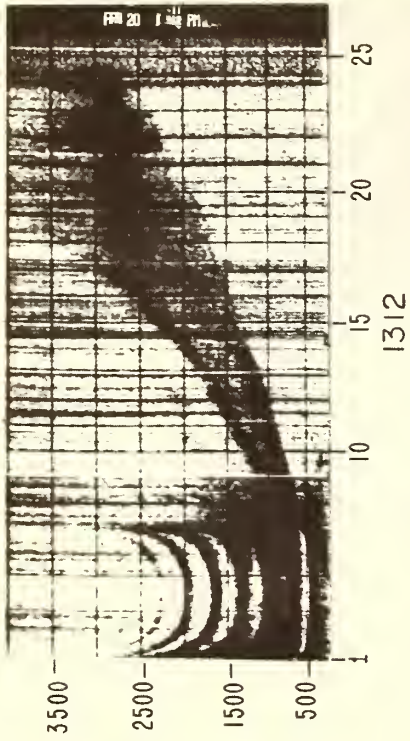
LPA → 150°



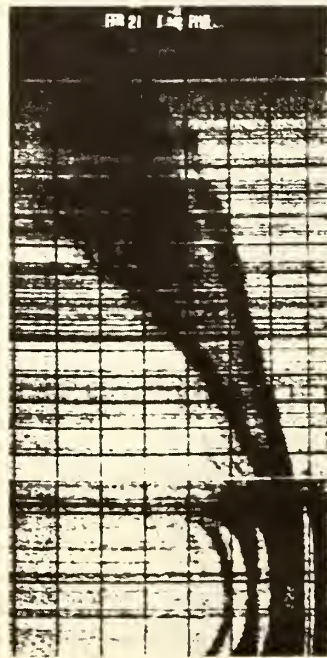
85165



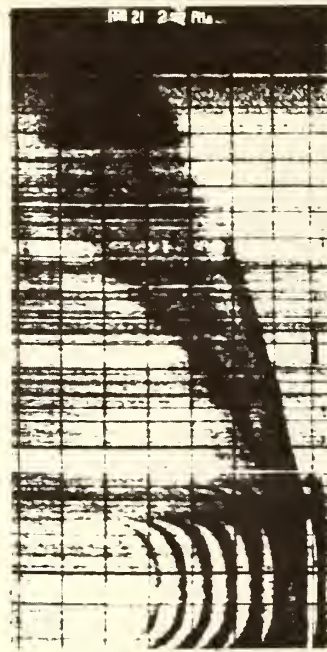
1219



20 February 1963

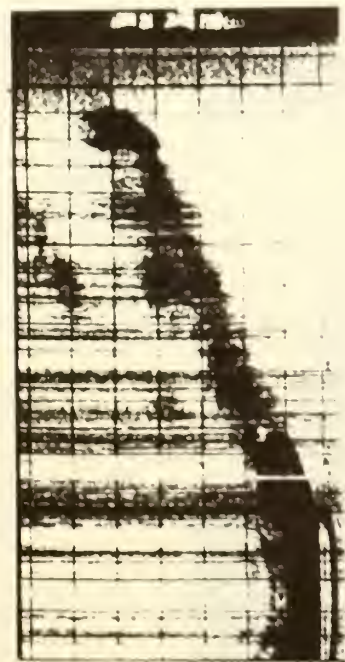


1342

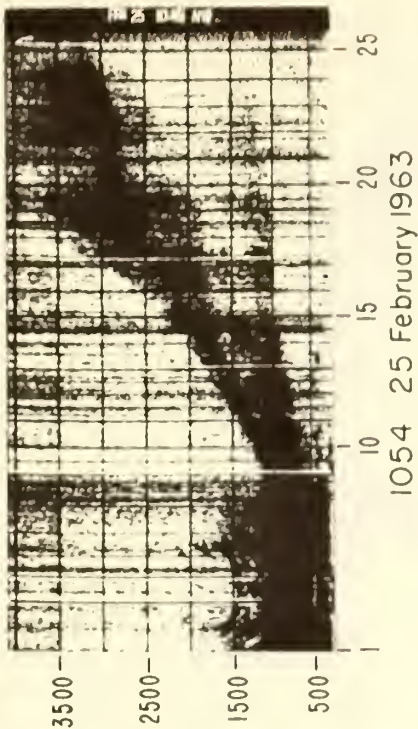


21 February 1427

LPA → 150°

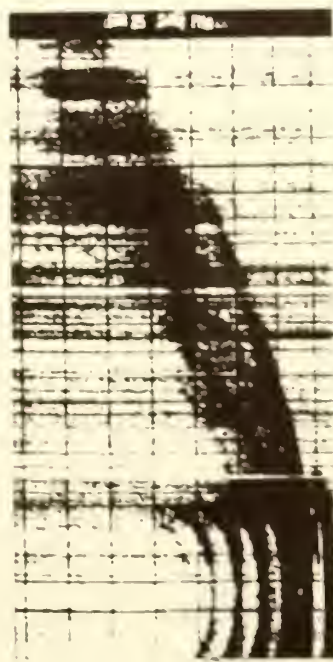


1542 21 February

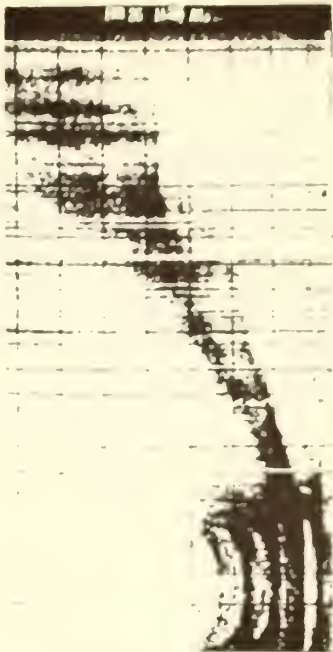


1054 25 February 1963

LPA → 150°



1432 25 February

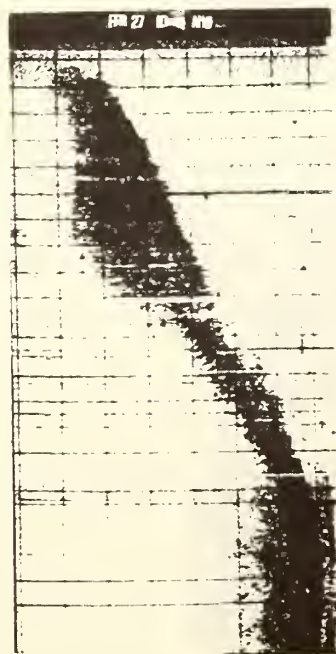


1100 26 February

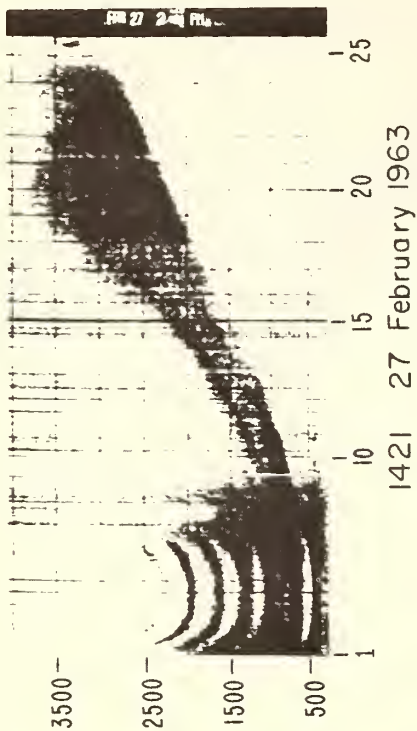
LPA → 150°

LPA → 114°

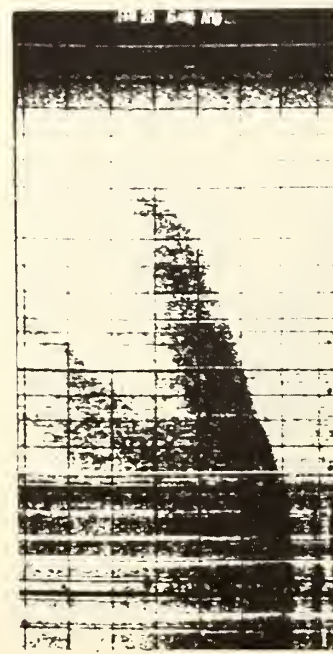




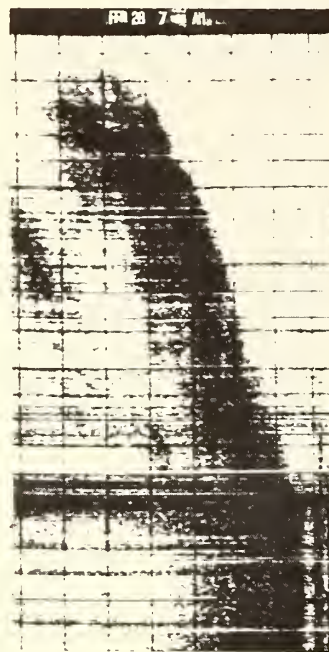
1035 27 February



LPA → 330°



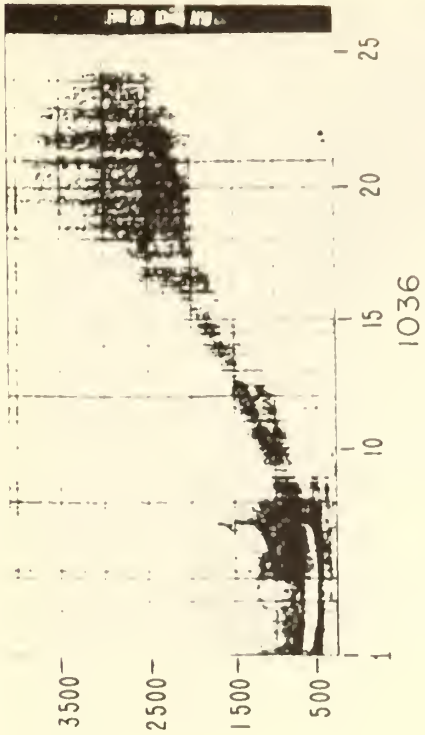
0636 28 February



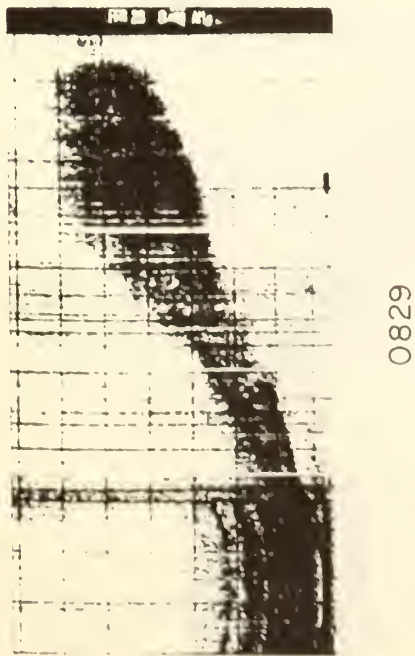
0706 28 February

LPA → 150°



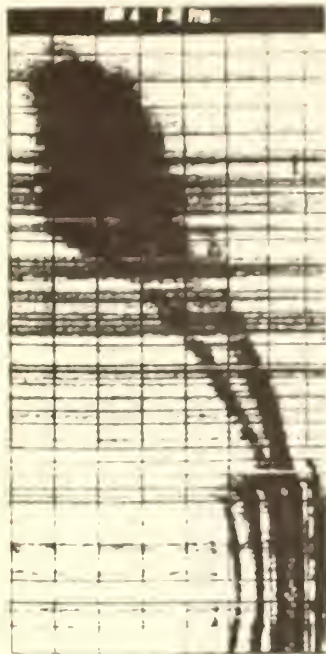


LPA → 150° 28 February 1963

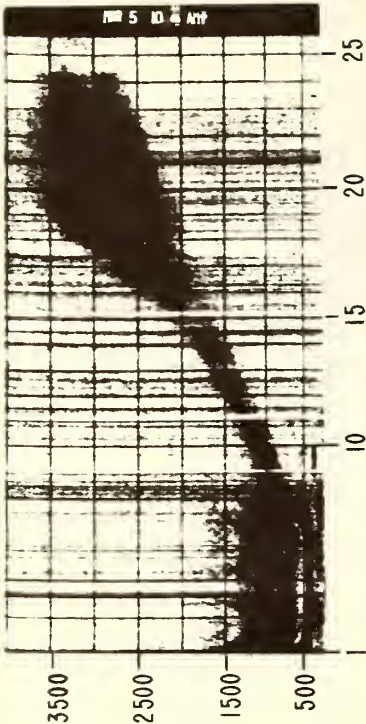


1202 28 February

LPA → 150°

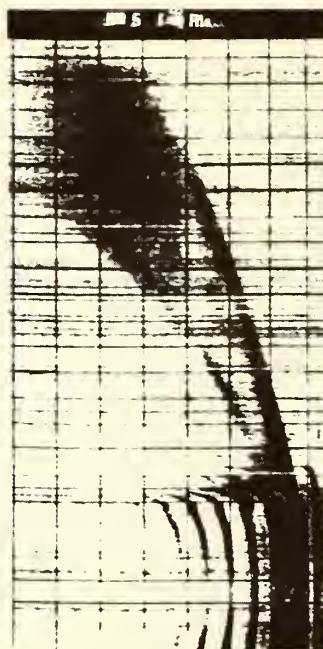


LPA → 114°



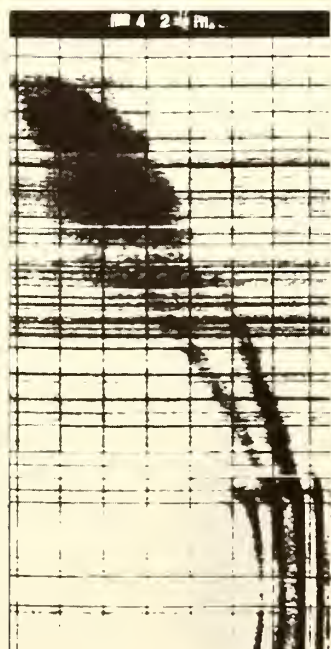
1045 5 March 1963

LPA → 270°



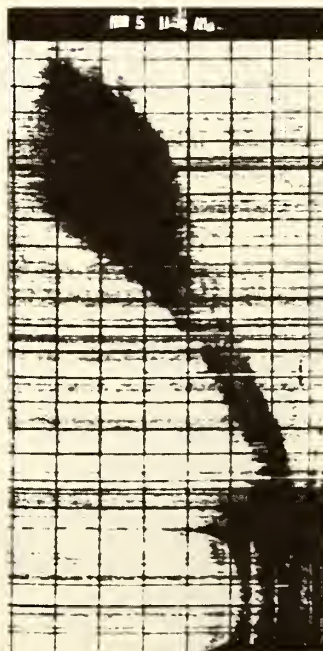
1328 5 March

LPA → 270°

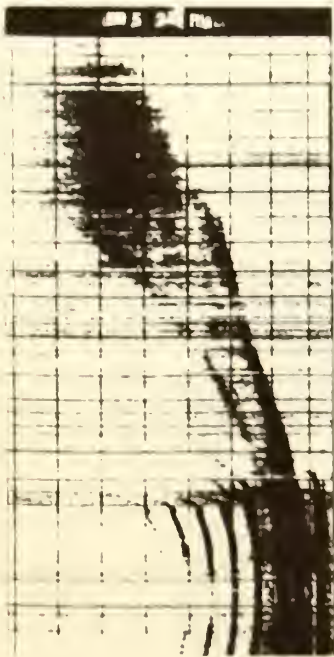


1418 4 March

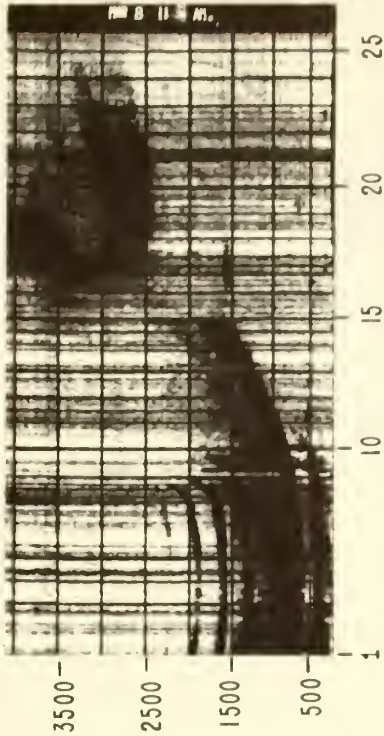
LPA → 114°



1132 5 March

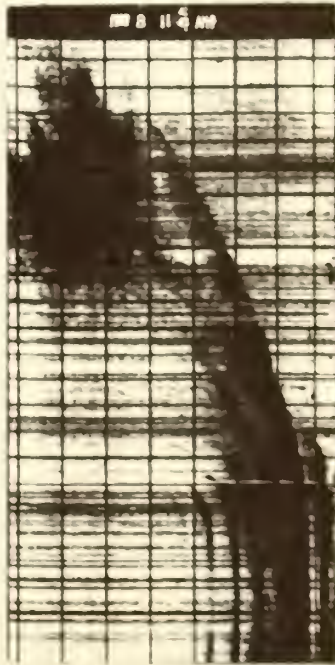


1431 5 March

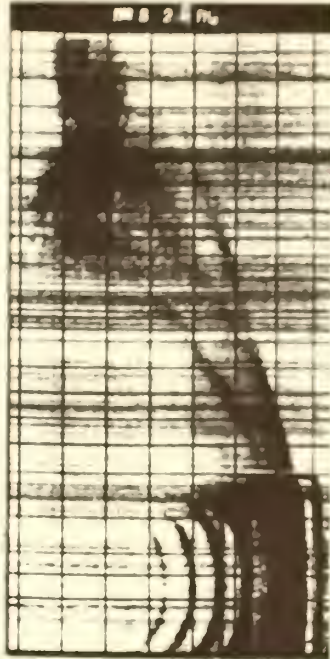


1124 8 March 1963

LPA → 270°



1143

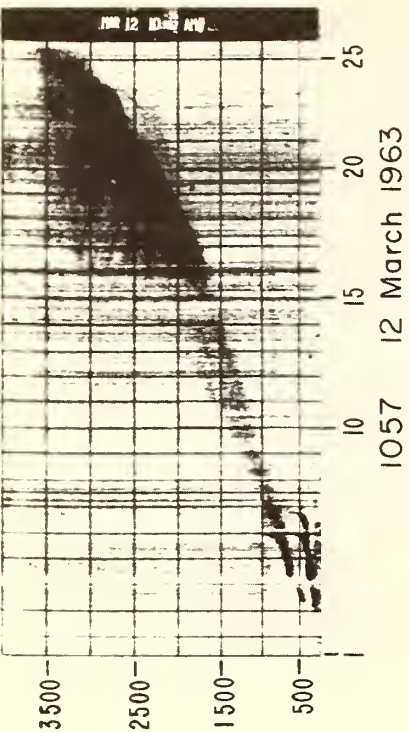


1431

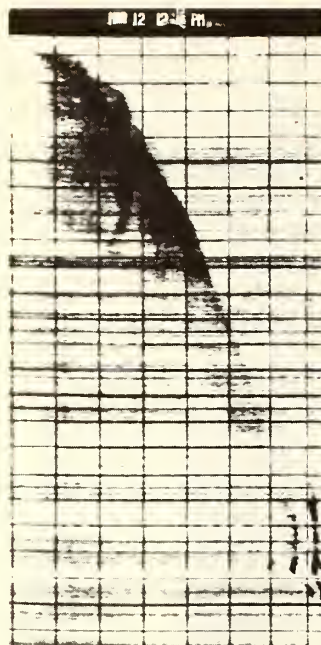
8 March 1963

LPA → 270°

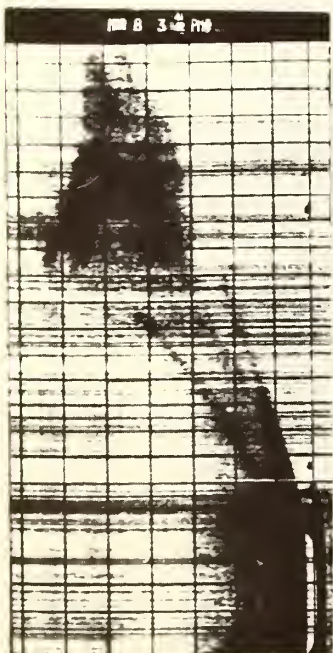




RHA → 114°

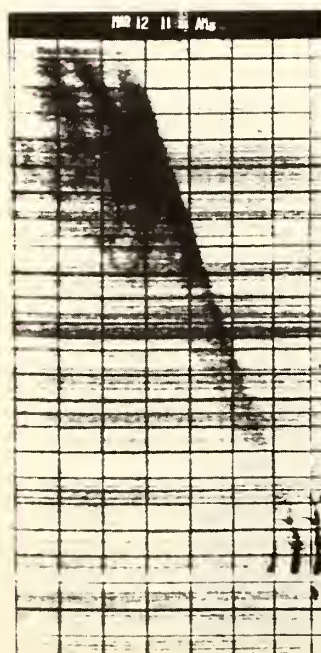


1216 12 March



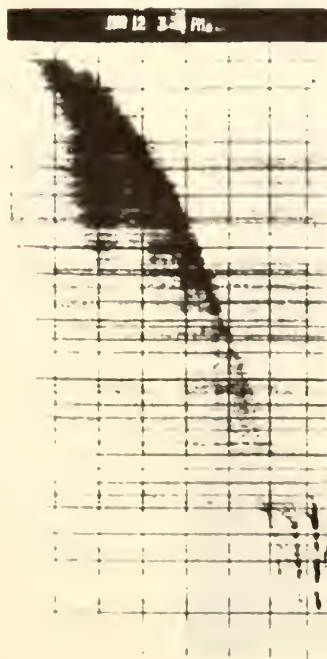
1542 8 March

LPA → 270°



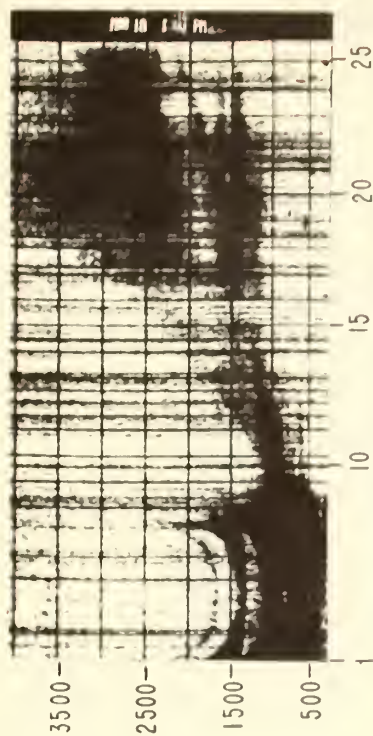
1134 12 March

RHA → 114°



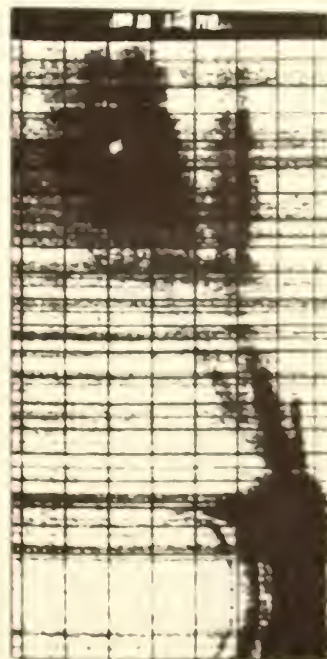
1523 12 March

RHA → 114°



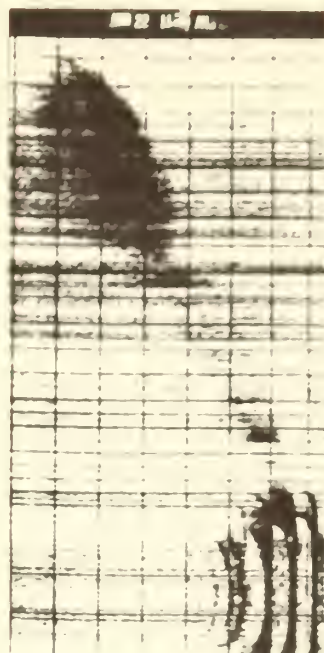
1311 18 March 1963

LPA → 270°



1345 18 March

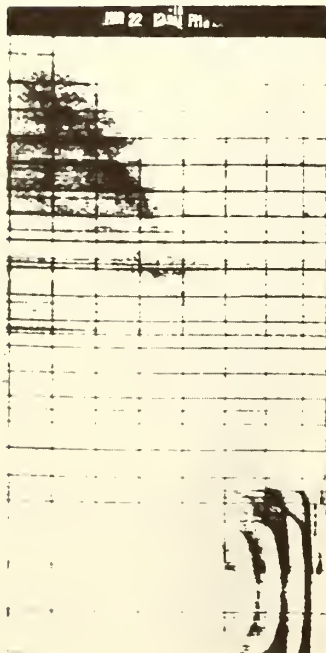
LPA → 270°



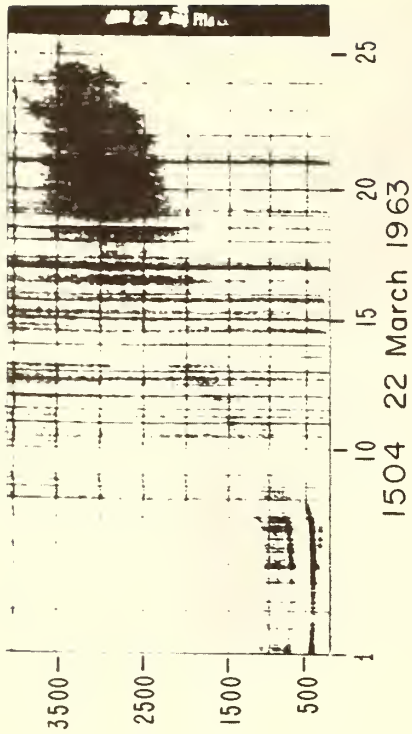
1100 22 March

LPA → 114°

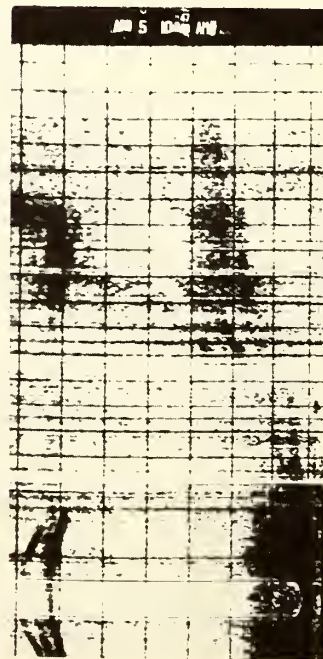
85172



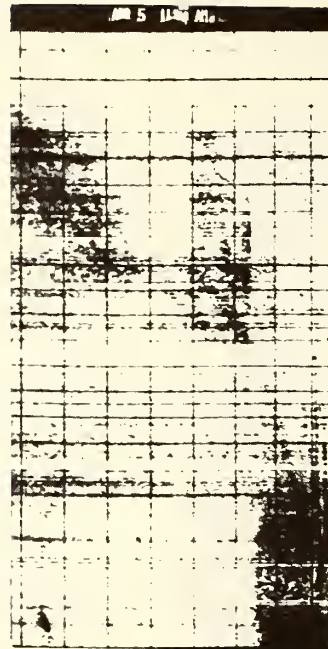
1211 22 March



LPA → 114°



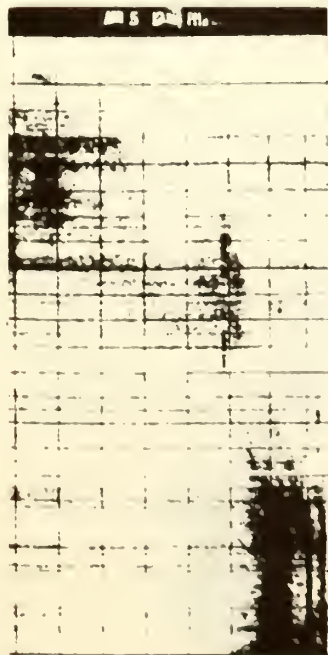
1048 5 April



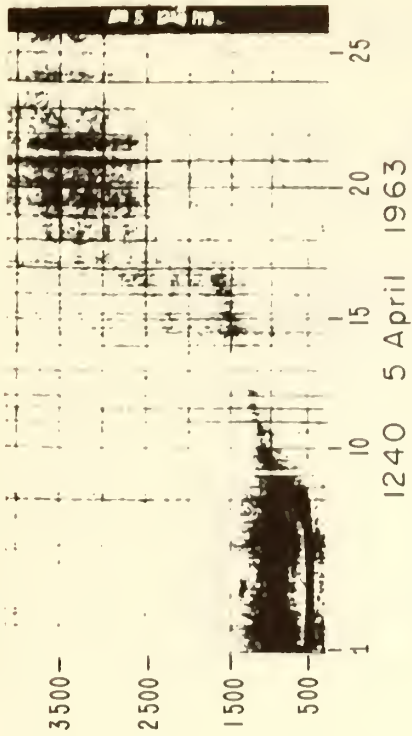
1110 5 April

LPA → 270°

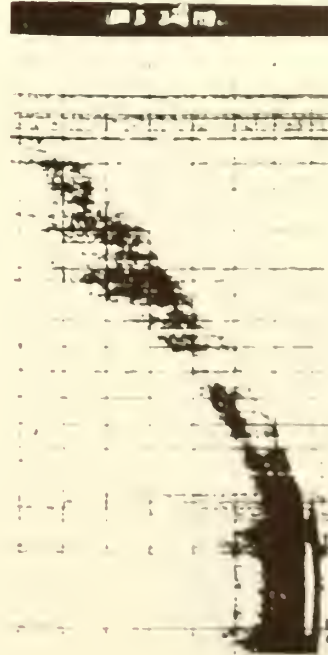




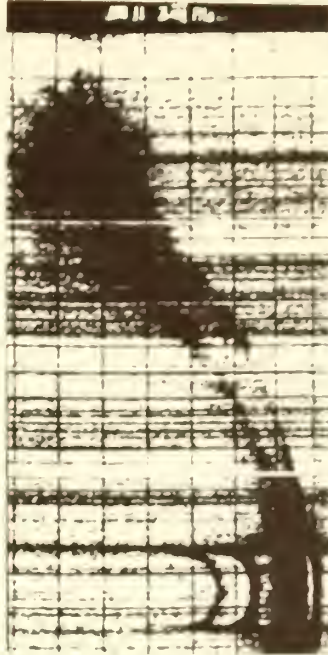
1203 5 April



LPA → 270°



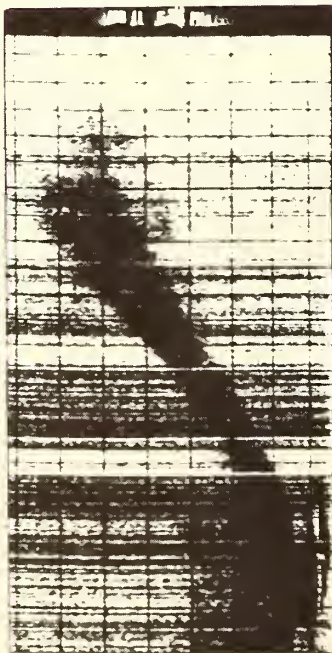
1544 5 April



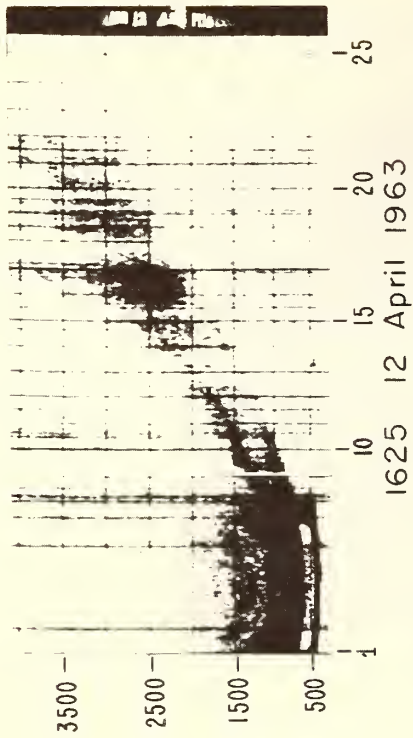
1521 11 April

LPA → 270°

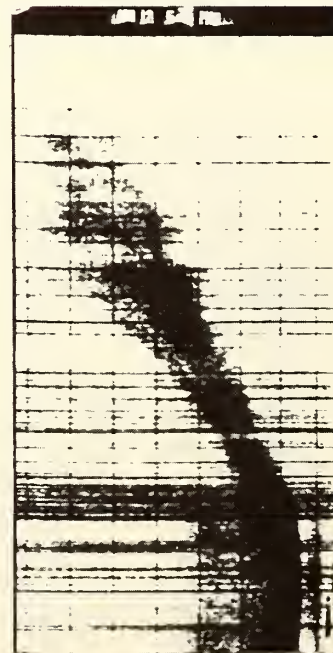
85160



1714 11 April

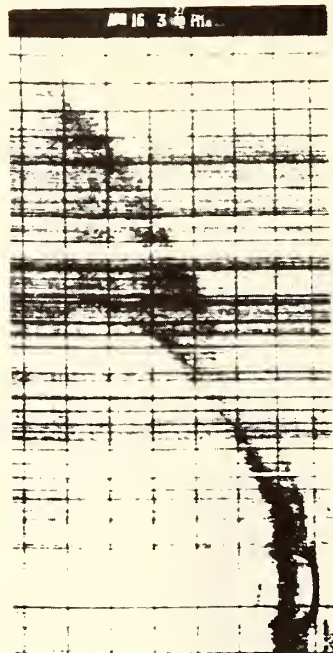


LPA → 270°



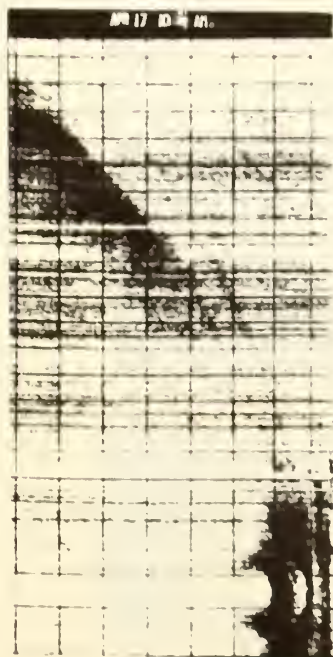
1736 12 April

LPA → 270°



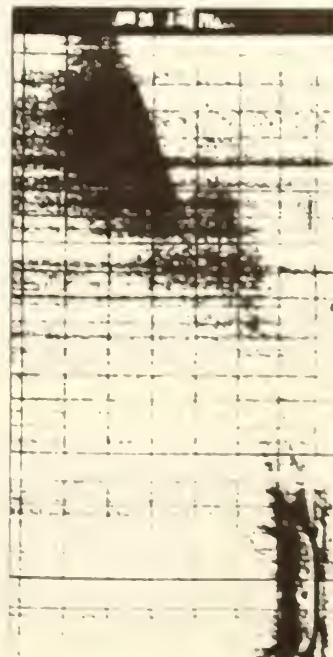
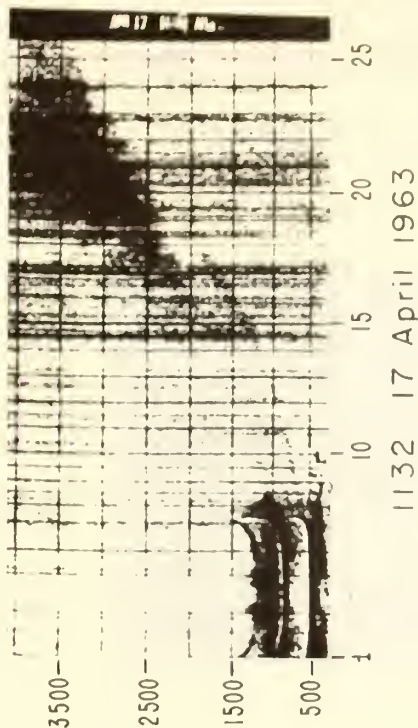
1528 16 April

LPA → 114°



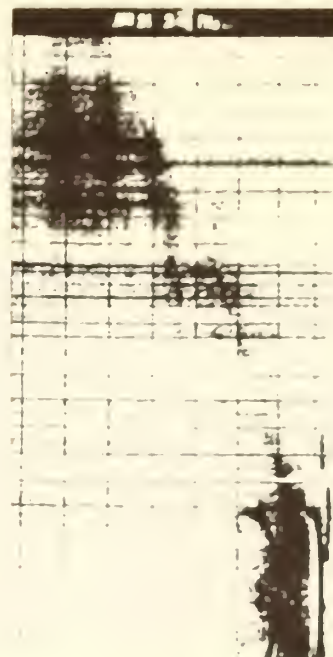
1002 17 April

LPA → 114°



1321 24 April

LPA → 180°

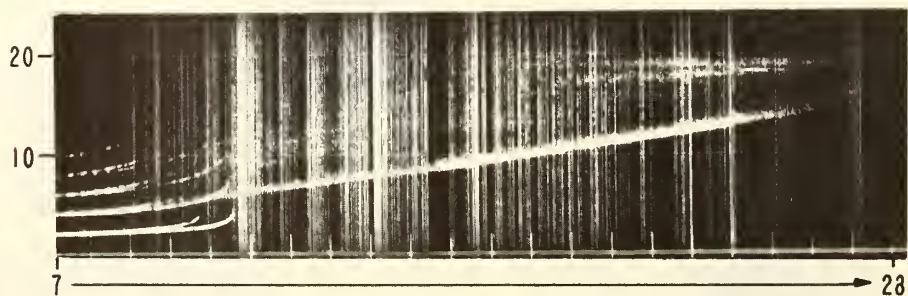
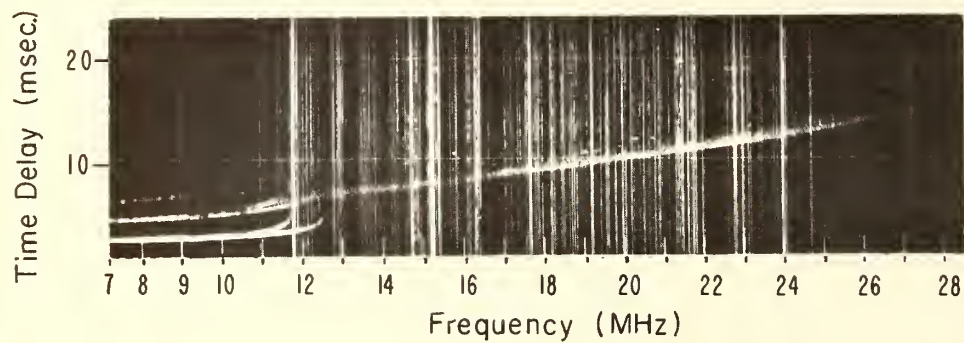


1421 24 April



NARROW-BEAM SWEEP-FREQUENCY BACKSCATTER

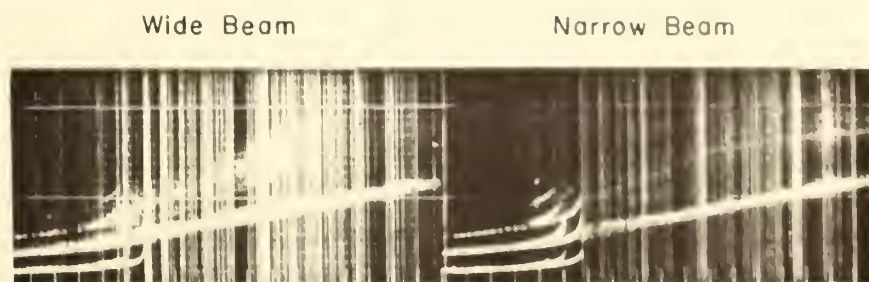
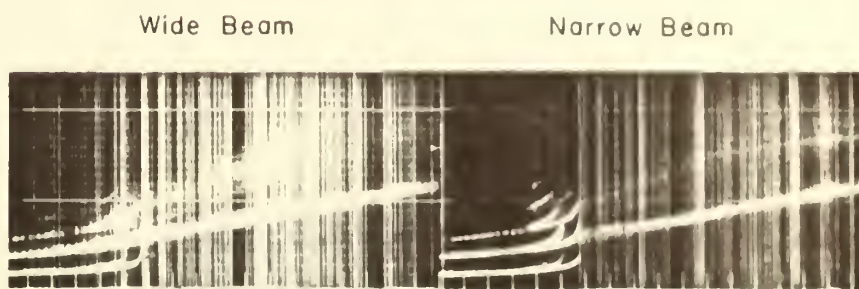
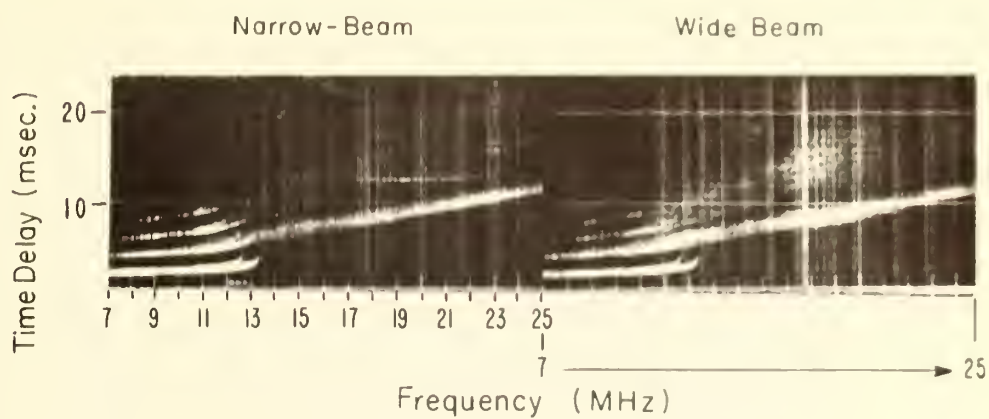
BOULDER, COLORADO - MARCH 1969



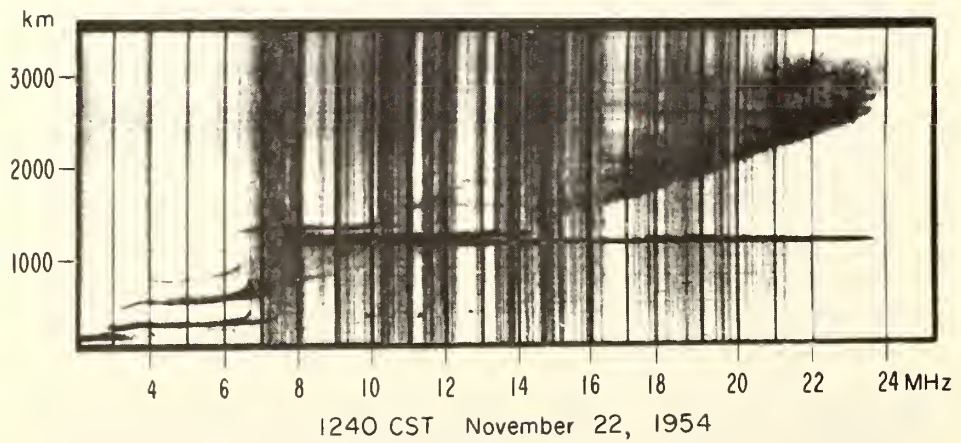
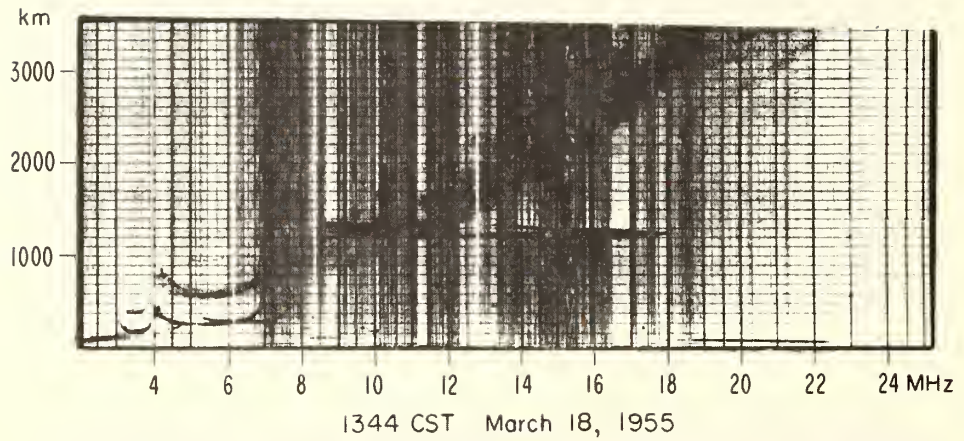
85157

# WIDE-BEAM/NARROW-BEAM SWEEP-FREQUENCY BACKSCATTER

BOULDER, COLORADO MARCH 1969



Simultaneous Vertical - Incidence,  
Oblique - Incidence Backscatter and  
Forward Pulse Sounding Data





## 6. PPI ROTATING ANTENNA, FIXED FREQUENCY BACKSCATTER

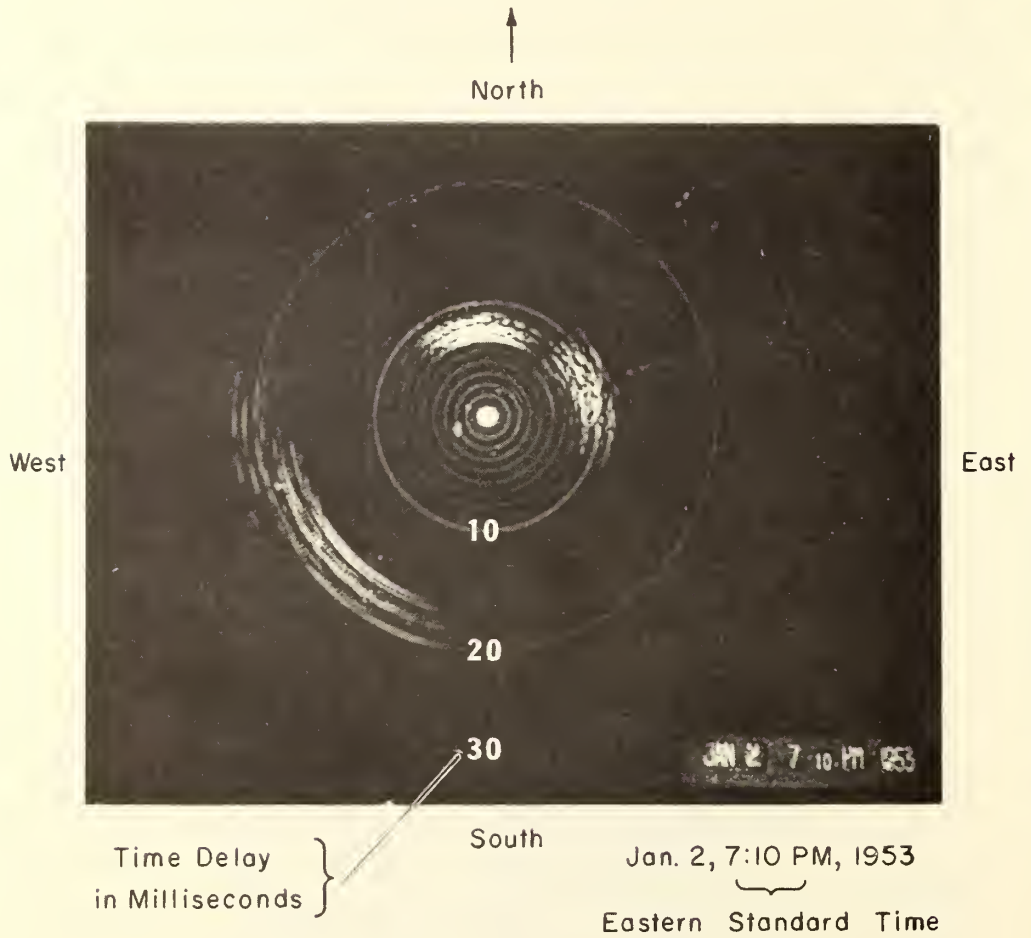
This section contains representative examples of PPI\* backscatter data obtained during winter 1952-1953 at the Central Radio Propagation Laboratory (CRPL)<sup>1</sup>, Sterling, Virginia, field site. The PPI<sup>1</sup> data format is shown on the following page, along with the important equipment parameters. Because of the multiplicity of different echo types shown on pages 89 through 103, no attempt has been made to classify the "signatures." A listing of the available data is included in the appendix following the sweep-frequency data listing.

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<sup>1</sup> Now the Institute for Telecommunication Sciences, ESSA.

<sup>2</sup> "Plan-position-indicator" - a term evolved from military radar system usage.

PPI DATA FORMAT



$f = 13.7 \text{ MHz}$

$P_0 \approx 200 \text{ kw}$

Pulse Length =  $60 \mu \text{ sec.}$

PRF = 25 Pulses/sec.

Antenna - Rotating Yagi,  $\sim 7 \text{ dB Gain}$

Location - Sterling, Virginia

83571



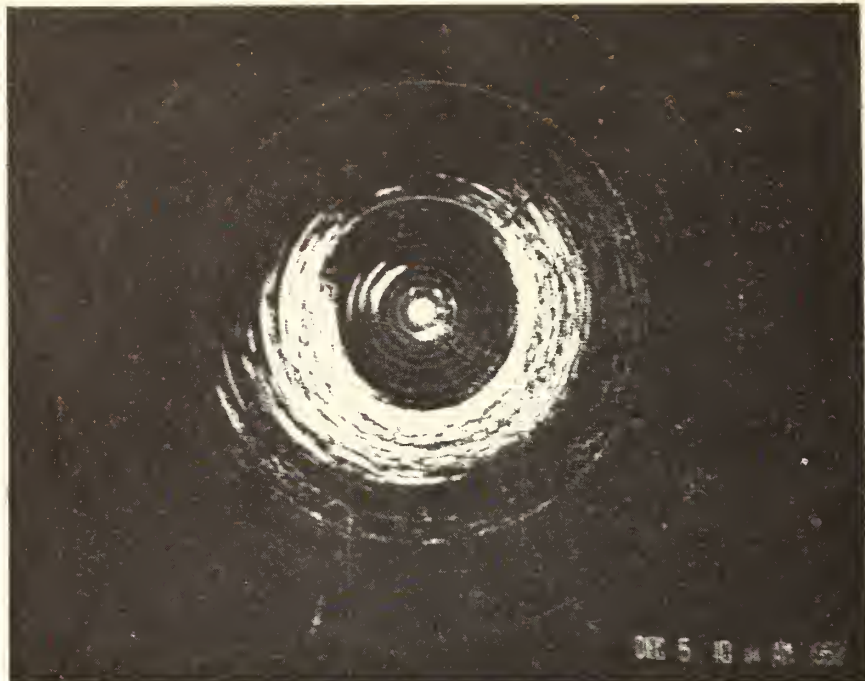
1650 EST 4 Dec. 1952



0405 EST 5 Dec. 1952

83556





1004 EST 5 Dec. 1952

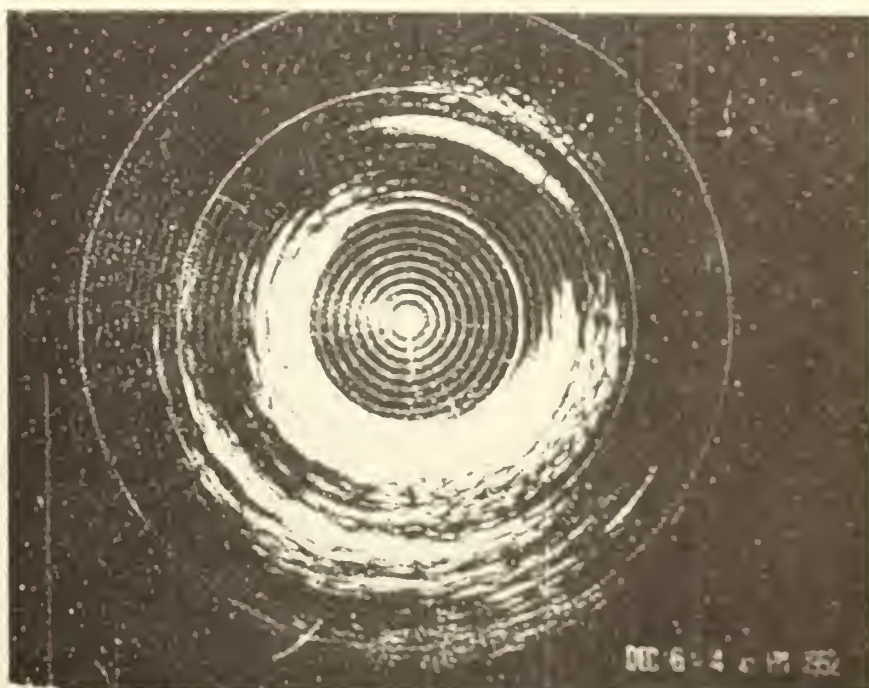


0158 EST 6 Dec. 1952

83557



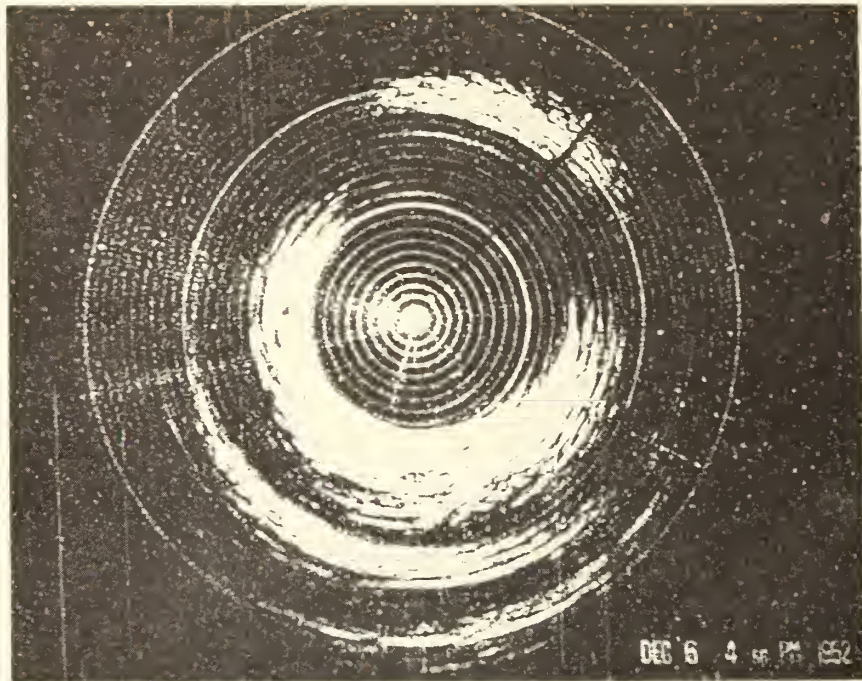
1209 EST 6 Dec. 1952



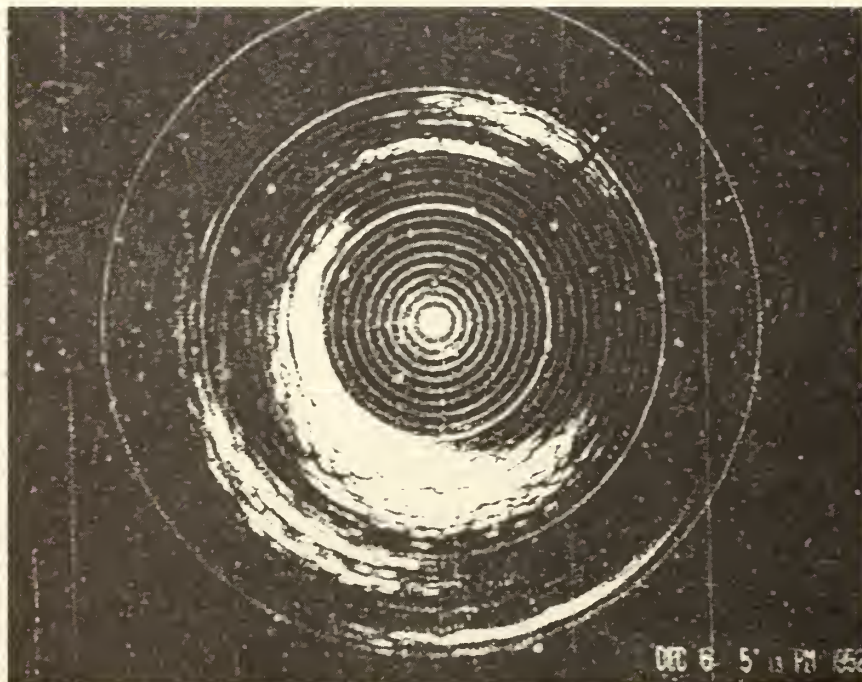
1647 EST 6 Dec. 1952

83558





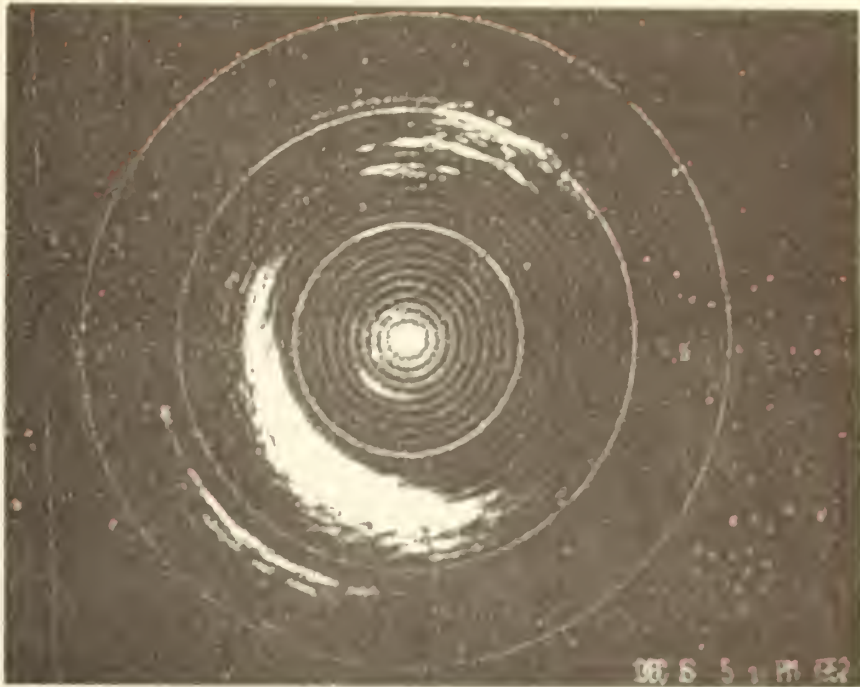
1655 EST 6 Dec. 1952



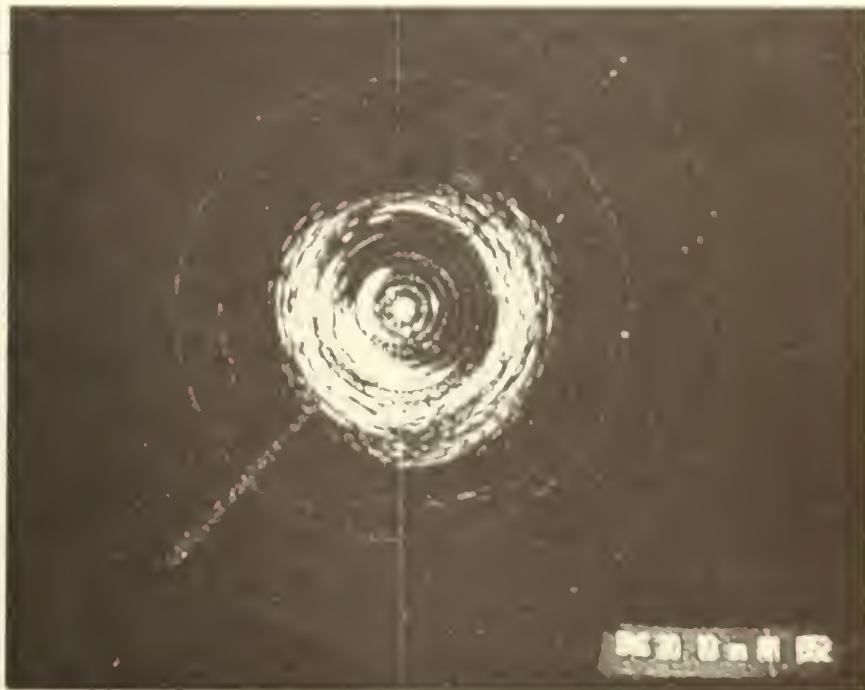
1713 EST 6 Dec. 1952

83559





1731 EST 6 Dec. 1952



1009 EST 20 Dec. 1952

83560

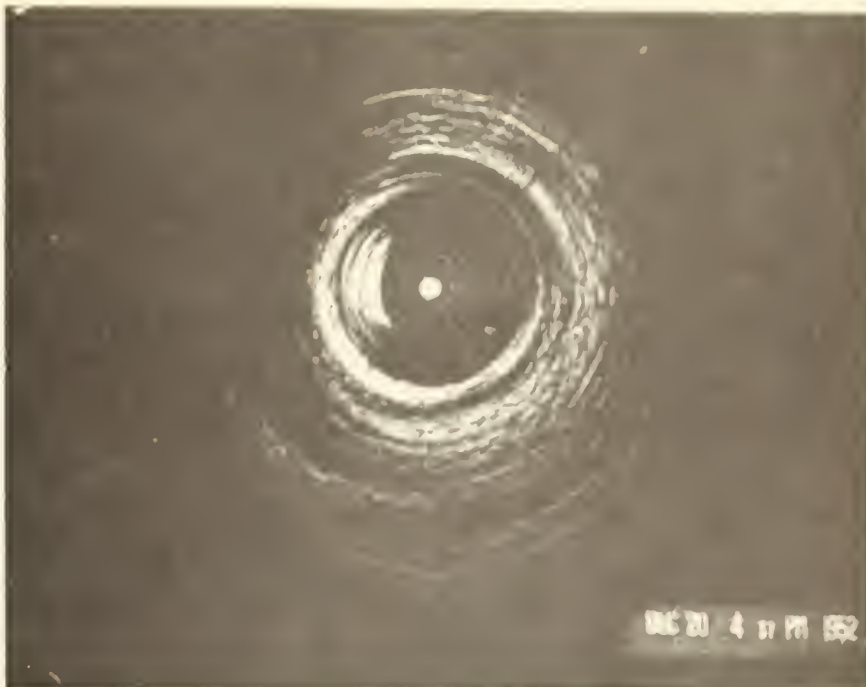


1249 EST 20 Dec. 1952

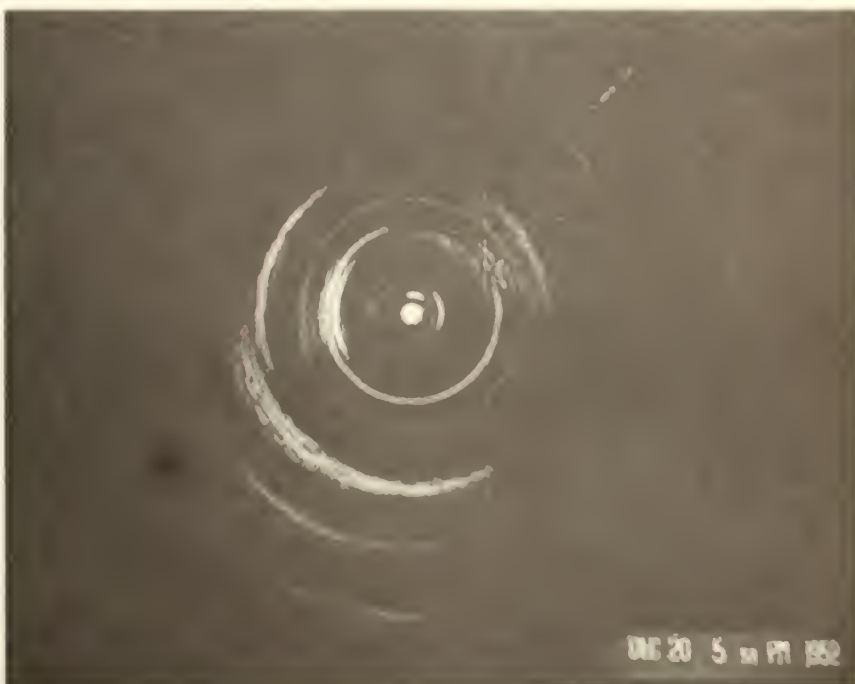


1503 EST 20 Dec. 1952

83561



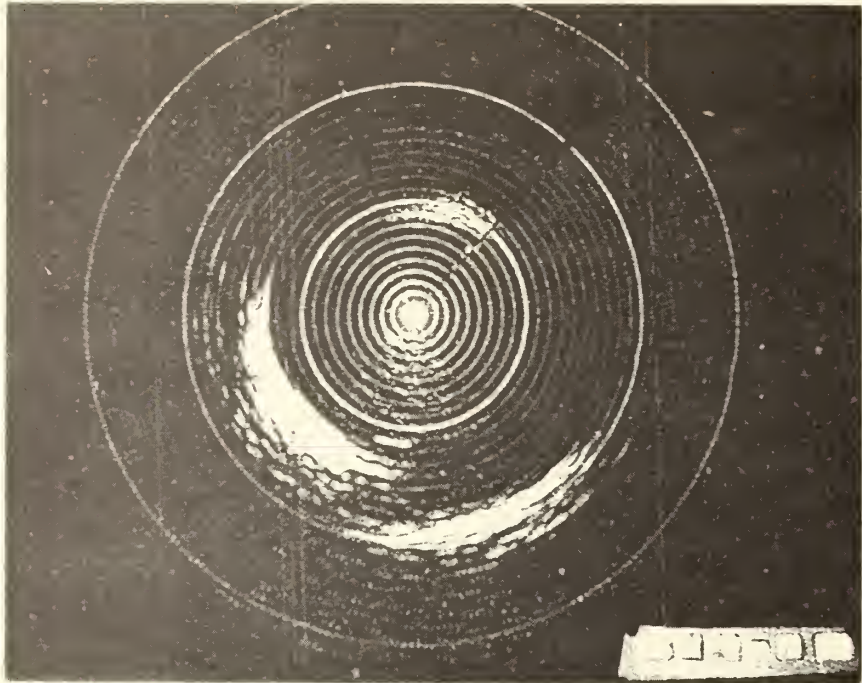
1637 EST 20 Dec. 1952



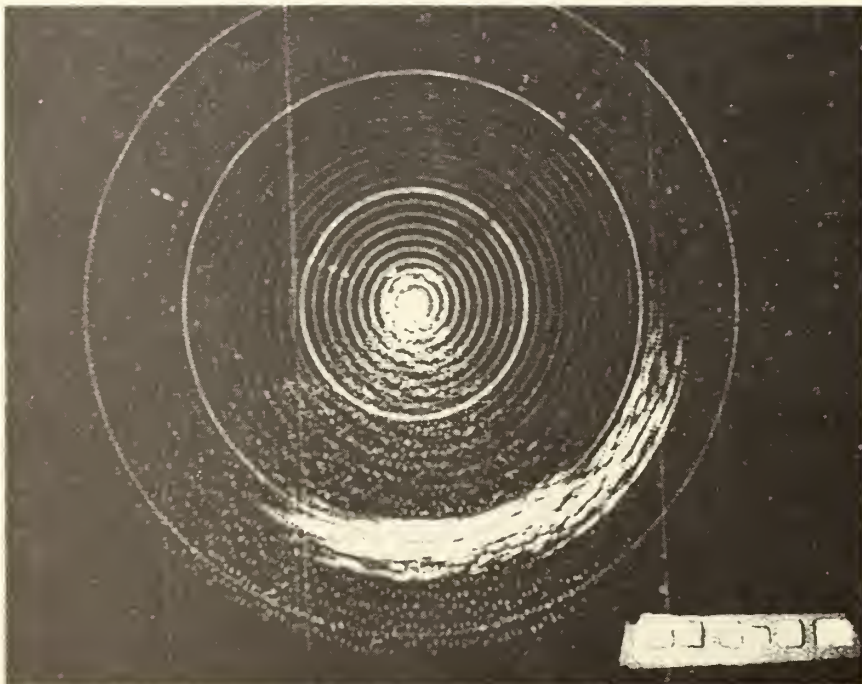
1759 EST 20 Dec 1952

83562



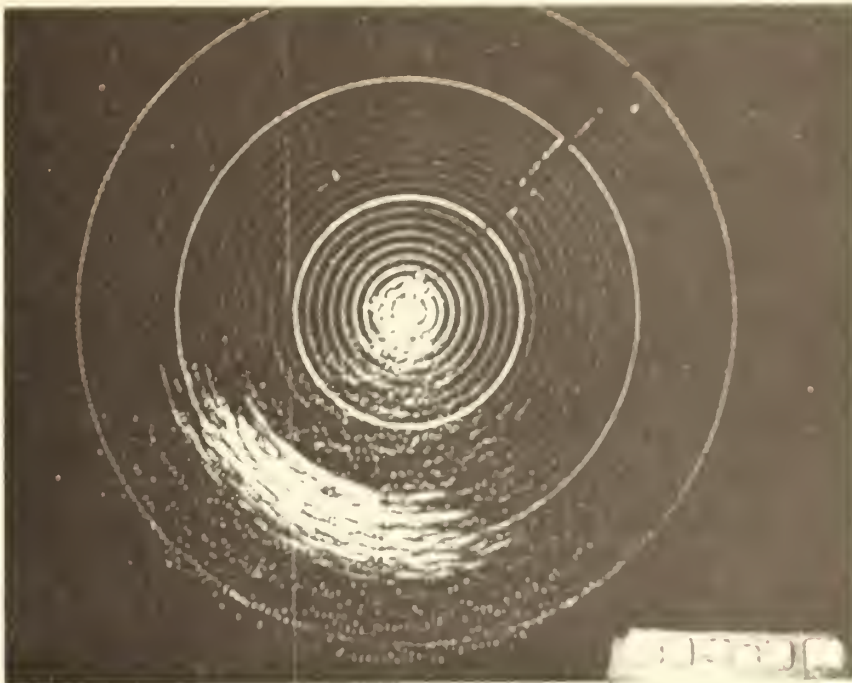


2040 EST 21 Dec. 1952

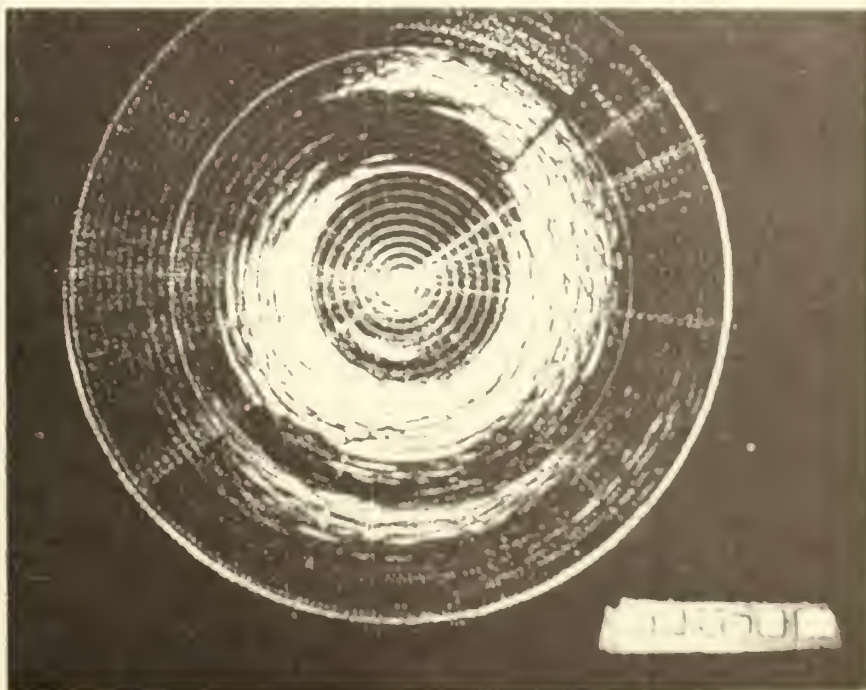


2259 EST 21 Dec. 1952

83563



0402 EST 28 Dec. 1952



1531 EST 28 Dec. 1952

83564



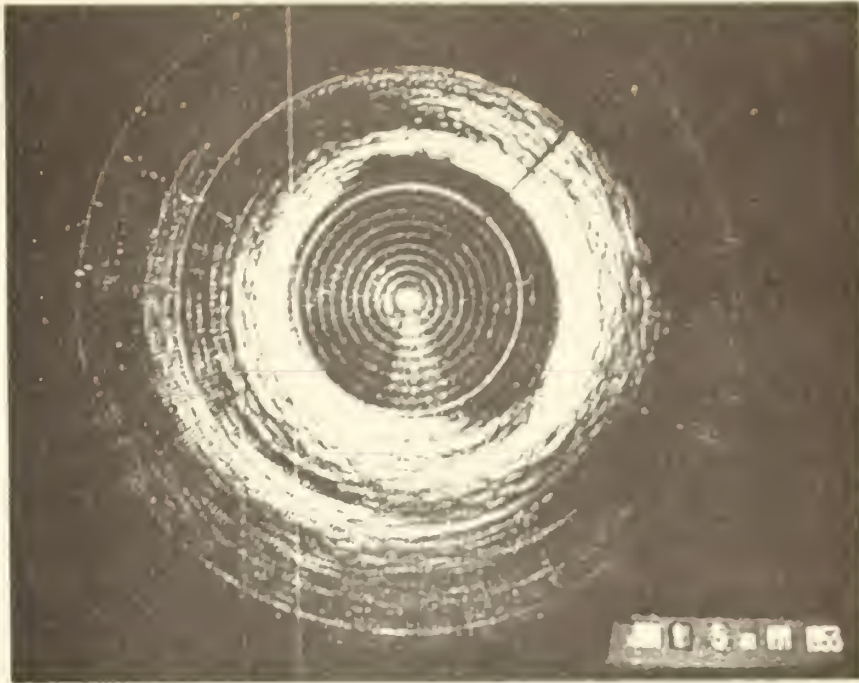
0523 EST 1 Jan. 1953



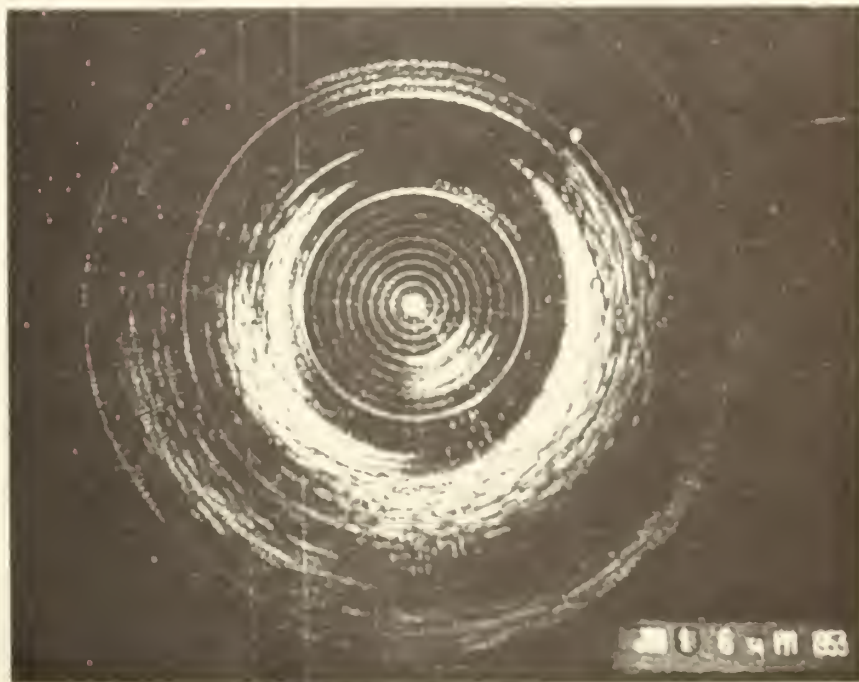
1522 EST 1 Jan. 1953

83565





1741 EST 1 Jan. 1953



1854 EST 1 Jan. 1953

83566

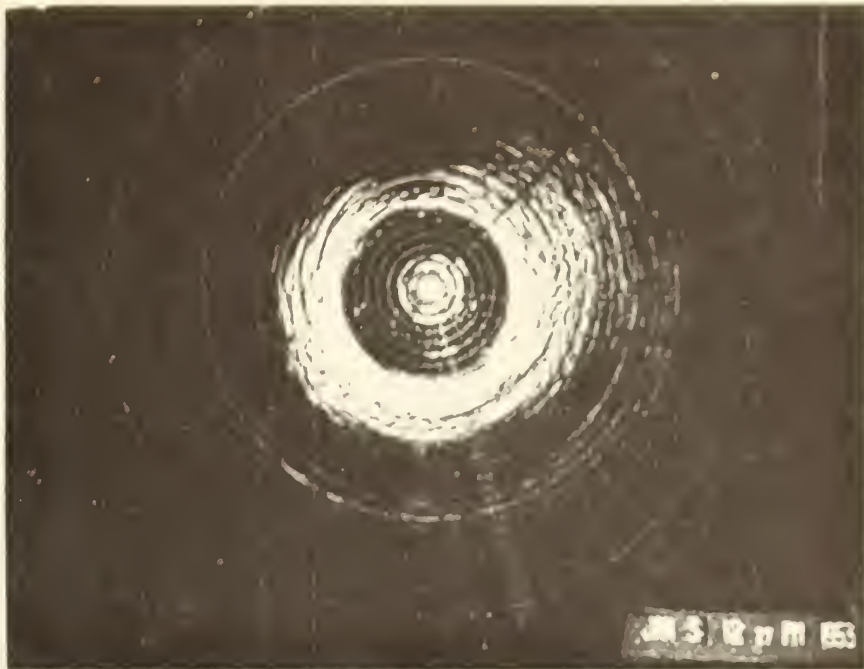


1952 EST 1 Jan. 1953



0122 EST 2 Jan. 1953

83567



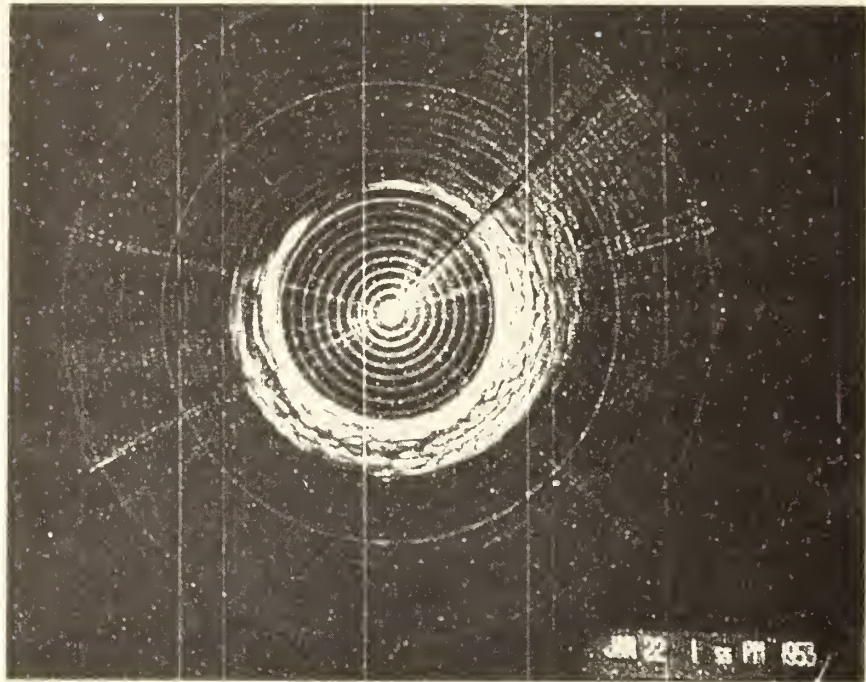
1227 EST 3 Jan. 1953



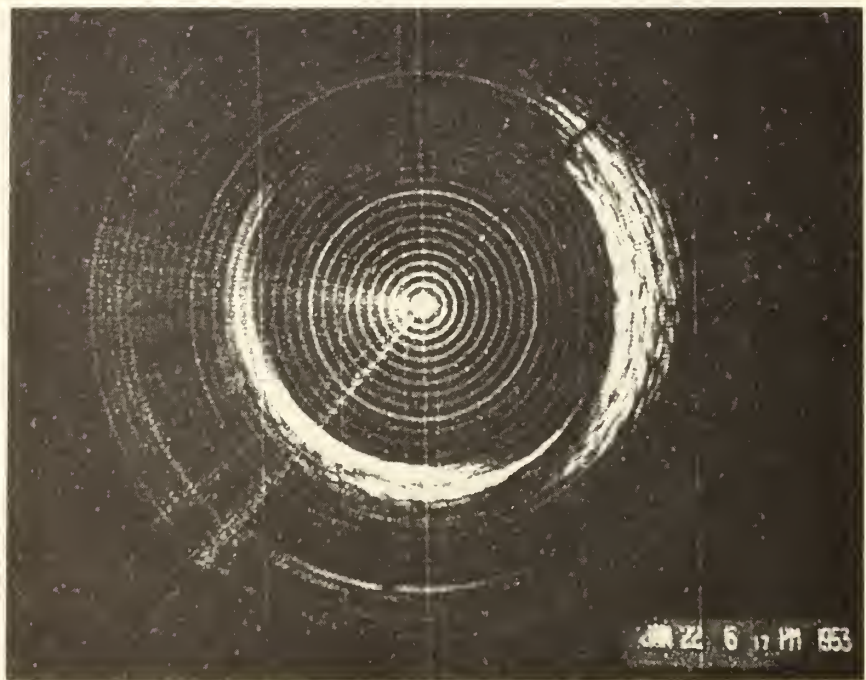
1628 EST 3 Jan. 1953

83568





1355 EST 22 Jan. 1953



1817 EST 22 Jan. 1953

83569



0307 EST 23 Jan. 1953



0941 EST 24 Jan. 1953

83570





## 7. ACKNOWLEDGMENTS

I would like to express my appreciation to several of my colleagues at ITS for aiding and abetting me on this project. To Mr. L. A. Berry, Mr. L. H. Tveten, Mr. R. K. Salaman, Dr. W. H. Hooke and Dr. T. M. Georges I am indebted for many stimulating and challenging discussions concerning the makeup of this atlas. Professor I. Ranzi of the Centro Radioelettrico Sperimentale "G. Marconi" in Rome, Italy provided good examples of range-time backscatter data for section 4 of this atlas.

Special thanks are also due to Mr. L. H. Tveten for making available to me vast quantities of backscatter film data and providing essential information needed to identify and catalog these data. My thanks also go to Mr. R. C. Kirby, (Director) and Dr. W. F. Utlaut (Deputy Director) of ITS for their support of this project.

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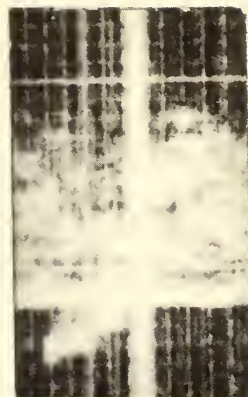
## APPENDIX

The tabulations on the left side of pages 110 through 122 in this appendix are listings of some backscatter sounding data which are available at the Boulder ESSA Research Laboratories. Sequences of the temporal behavior of two of the "signatures" observed with the narrow-beam azimuth and elevation scan radar are shown on the right side of pages 110 through 132. The data were acquired every two minutes and some idea of the irregularity motion may be obtained by rapidly flipping the pages. The upper photos show the time behavior of the "patch" signature, and the lower photos illustrate apparent motion of the "bands" signature.

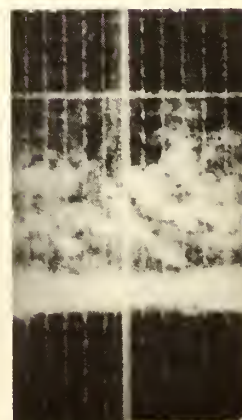
Range-Azimuth and Range-Elevation  
Scan Backscatter - 16 mm Film Data

<u>Date</u>	<u>Start</u>	<u>End</u>	<u>Type of "Signatures"</u>
Roll #64/ 65-01		<u>MST</u>	
1964			
Oct. 16	1050	1500	MSB, FS
19	0645	1800	MSB, FS, T, P
19	1830	2400	MSB, FS, P
20	0000	0600	MSB, P, FS
21	0600	1815	MSB, FS, T
22	0715	1730	MSB, FS, P, LB, T
23	0800	1130	MSB, FS
23	1200	1600	MSB, FS, B
Nov. 5	0830	1530	MSB, FS
9	0715	1845	MSB, FS, T, LB
11	0615	0700	MSB, T
11	1700	1743	P
13	0620	0725	T, MSB, FS
13	1700	1800	MSB, FS
17	0612	0654	T, MSB
17	1600	1715	B
18	0615	0907	MSB, FS
19	1650	1740	P
21	1555	1700	LB, FS
23	1130	1600	LB, MSB
Dec. 8	0930	Dec. 9 0347	MSB, FS, H
10	1508	1640	LB, MSB, FS
11	1316	1455	MSB, FS
14	1223	1334	MSB, FS
15	0715	2040	MSB, FS, B, H, P
15	2055	2400	P, LB
16	0000	~1600	MSB, FS, T
29	~1000	1635	MSB, FS, T
30	1000	1135	MSB, FS
31	1010	1100	MSB, FS, T
1965			
Jan. 4	0920	1320	LB, MSB, FS
6	1005	1507	MSB
7	0805	1145	MSB, FS, T
7	1223	2200	MSB
82817 8	0023	1530	MSB, FS, T, P

0843



1300

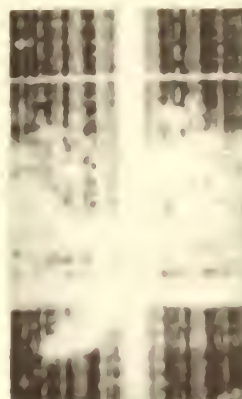




Range-Azimuth and Range-Elevation  
Scan Backscatter - 16 mm Film Data

Date	Start	End	Type of "Signature"
Roll #64/ 65-01		MST	
1965			
Jan. 11	1045	1110	MSB
13	1545	1615	MSB, FS
14	1216	~1300	
20	0920	1625	MSB
23	0830	0920	MSB
25	0920	1000	
Feb. 11	1735	1850	MSB, FS
Roll No. 65-01			
May 4	0900	1800	MSB, FS, T
5	1830(6)	0630	MSB
17	1100	1850	P, MSB, FS, LB
7	2205	1445(19)	P, MSB, FS, LB, T, U
Roll No. 65-02			
June 2	1030	2400	MSB, T, P, LB
3	0000	1515	MSB, P, T, FS
7	0925	1330	MSB, LB, P
8	1125	1445	MSB, LB
9	1000	2400	T, MSB, P
10	0000	1430	U, P, LB, MSB, FS, T
21	1100	1300	MSB, FS
Roll No. 65-03			
June 25	0905	1040	MSB, FS, P
28	1145	2400	LB, MSB, FS
29	0000	2400	LB, MSB, FS
30	0000	1100	LB, MSB
Roll No. 65-04			
July 1	1255	1450	LB, MSB, FS
2	0900	1045	MSB, FS
6	0950	2400	LB, MSB, T
7	0000	2400	LB, P, T, MSB, FS
8	0000	1315	MSB, T
Roll No. 65-05			
July 8	1410	1545	LB, MSB, FS
12	0925	1010	MSB, FS
13	0020	0135	MSB, FS

0845



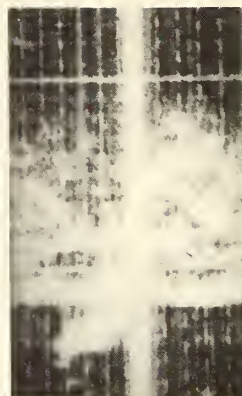
1302



Range-Azimuth and Range-Elevation  
Scan Backscatter - 16 mm Film Data

Date	Start	End	Type of "Signature"
Roll No. 65-05	<u>MST</u>		
July 14	0900	2400	MSB, FS, P, T
15	0000	2400	MSB, FS, P, T, H
16	0000	1335	MSB, FS, P
Roll No. 65-06			
July 19	0730	1030	MSB, FS
19	1820	1944	MSB, FS, P
20	0850	2400	MSB, FS, LB, P, T
21	0000	1520	MSB, LB, P, T
22	0000	1520	MSB, FS, T
Roll No. 65-07			
July 27	0905	2400	LB, MSB, FS, T, P, U
28	0000	2400	FS, MSB, P, T
29	0000	~1430	FS, MSB, LB, P
1966			
Roll No. 66-01			
Jan. 24	1110	1620	LB, MSB, FS
25	1110	1650	MSB, FS, B
26	1210	1625	MSB, FS, P
Roll No. 65-08a			
Aug. 3	1045	2400	MSB, FS, T
4	0000	2400	MSB, FS, T, U, LB
5	0000	0400	MSB, FS
Roll No. 65-08b			
Aug. 10	1115	2400	MSB, LB, P, FS, T
11	0000	2400	MSB, T, LB
Roll No. 66-02			
Aug. 17	2000	2400	LB, P
18	0000	2400	MSB, T, B, H
19	0000	2400	FS, MSB, T
20	0000		FS, MSB, T, P
Roll No. 66-03			
Sept. 12	1725	2400	FS, MSB, T
13	0000	2400	FS, MSB, T
14	0000	2400	FS, MSB, T
82815 15	0000	2400	FS, MSB, T, LB

0847



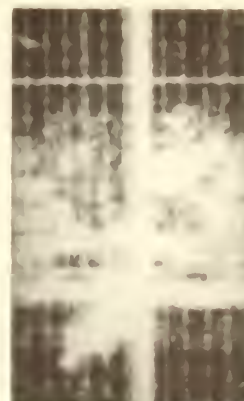
1304



Range-Azimuth and Range-Elevation  
Scan Backscatter - 16 mm Film Data

Date	Start	End	Type of "Signature"
Roll No. 66-03		<u>MST</u>	
Sept. 16	0000	2400	FS, MSB, T, LB
17	0000	1730	
Roll No. 66-04			
Oct. 10	2015	2400	T, P, H, MSB, FS
11	0000	2400	LB, MSB, FS, B
12	0000	2400	U, LB, MSB, FS, B
13	0000	2400	LB, MSB, FS, B
14	0000	2400	U, MSB, FS, B
15	0000	1000	MSB, FS
Roll No. 66-05			
Nov. 15	1350	1900	U, MSB, H
15	2030	2400	P, LB, MSB
16	0000	1130	U, H, P, B
16	1930	2400	U, H
17	0000	2400	FS, B, U, P
18	0000	1300	LB, U, P, FS
19	0130	1740	U, P, FS, B
Roll No. 66-06			
Dec. 14	1637	2400	MSB, H, FS
15	0000	2400	B, P, MSB, FS
16	0000	2400	FS, H, MSB, FS, B, T, P
17	0000	1730	H, MSB, FS, B
1967			
Roll No. 67-01			
Jan. 18	1820	2400	MSB, FS, LB, B
19	0803	1910	H, FS
19	1918	2400	LB, MSB
20	0745	~1700	T, H, MSB, FS
20	1758	2400	T, H, MSB, FS
21	0025	0441	T, MSB, FS, H
21	0524	1701	T, MSB, FS, B
Roll No. 67-02		<u>UT</u>	
Feb. 14	1430	2400	MSB, FS, T, B
15	2149	2400	MSB, FS, B
16	0038	2400	MSB, FS, T, B
82814 17	0000	2400	MSB, FS, B
18	0000	2400	MSB, FS, B, H

0849



1306

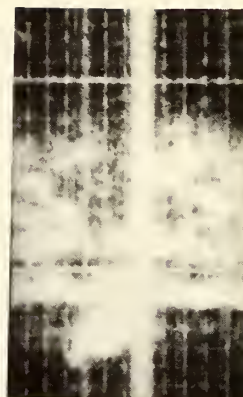




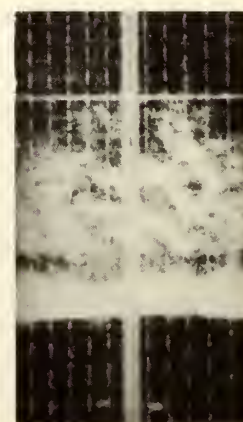
Range-Azimuth and Range-Elevation  
Scan Backscatter - 16 mm Film Data

<u>Date</u>	<u>Start</u>	<u>End</u>	<u>Type of "Signature"</u>
Roll No. 67-03A <u>UT</u>			
Mar. 14	1538	2400	U, FS, B
	15 0000	2400	U, FS, B
	16 0000	2400	U, FS, B
	17 0000	2400	U, FS, B
	18 0000	2400	U, FS, B, MSB
Roll No. 67-03B			
Mar. 14	1420	2400	B
	15 0000	2400	B
	16 0000	2400	B, T
	17 0000	2400	T, LB, B
	18 0000	2400	B, LB
Roll No. 67-04			
Apr. 11	0515	2400	MSB, T, U, FS
	12 0000	2400	U, FS, MSB, T
	13 0000	2400	U, FS, MSB, T, B
	14 0000	2400	U, FS, B
	15 0000	2400	U, FS, T, P
Roll No. 67-05A			
May 9	0115	2400	B, U, MSB, FS, P
	10 0000	2400	U, FS, H, P, T, MSB
	11 0000	2400	MSB, LB, T, P
	12 0000	2400	MSB, LB, FS, H, T, P
	13 0000	2400	LB, MSB, FS, P, T
Roll No. 67-05B			
May 22	2030	2240	FS, T, MSB
	23 1530	1830	U, FS, T
	23 2030	2130	FS, T
	24 1520	2300	MSB, FS, T, P
	25 1500	2100	B, FS, P, MSB, T
Roll No. 67-06			
June 13	0345	2400	LB, MSB, FS, P, B
	14 0000	2400	U, FS, MSB, P, H
	15 0000	2400	P, H, T, MSB, LB
	16 0000	2400	U, MSB, P, FS
	17 0000	2400	P, MSB, P, FS

0851



1308



Range-Azimuth and Range-Elevation  
Scan Backscatter - 16 mm Film Data

Date	Start	End	Type of "Signature"
Roll No. 67-07		UT	
July 18	0630	2400	MSB, T, P, FS
19	0000	2400	MSB, P, FS
20	0000	2400	MSB, FS, P, H, T
21	0000	2400	MSB, FS, P
22	0000	1030	MSB, FS, LB
Roll No. 67-08			
Aug. 15	0020	2400	MSB, FS, T, P, B
16	0000	2400	P, T, MSB, FS, B
17	0000	2400	MSB, FS, LB, T
18	0000	2400	MSB, FS, T
19	0000	2400	MSB, FS, P, H
Roll No. 67-09			
Sept. 19	0000	2400	U, FS, MSB, B, P, T
20	0000	2400	MSB, LB, FS, T
21	0000	2400	U, FS, P, B, LB, H, T, MSB
22	0000	2400	U, FS, P, MSB
23	0000	2400	LB, FS, MSB, B, U
Roll No. 67-10			
Oct. 24	1500	2400	U, MSB
25	0000	2400	U, FS, MSB, P
26	0000	2400	U, FS, MSB
27	0000	2400	U, FS, B
28	0000	2400	U, FS, MSB
Roll No. 67-11			
Nov. 14	0130	2400	B
15	0000	2400	U, FS
16	0000	2400	U, FS, MSB
17	0000	2400	U, FS, MSB
18	0000	2400	
Roll No. 67-12			
Dec. 12	1030	2400	U, FS, MSB, B
13	0000	2400	B, U, MSB, B
14	0000	2400	MSB, FS, B
15	0000	2400	MSB, T, U, FS
16	0000	2400	U, MSB, FS, B

0853



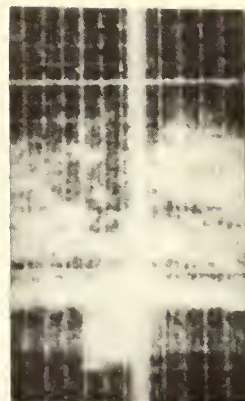
1310



Range-Azimuth and Range-Elevation  
Scan Backscatter - 16 mm Film Data

Date	Start	End	Type of "Signature"
Roll No. 68-01	UT		
Jan. 16	0445	2400	FS, MSB, P, T, U, B
17	0000	2400	MSB, FS, T, B
18	0000	2400	MSB, FS, B
19	0000	2400	MSB, LB, FS, B
20	0000	2400	MSB, LB, FS, T
Roll No. 68-02			
Feb. 20	0100	2400	MSB, FS
21	0000	2400	MSB, FS, LB, B, T
22	0000	1800	T, MSB, FS, B
23	0007	2400	T, FS, MSB, P, B
24	0000	2400	P, MSB, FS, B, LB
Roll No. 68-03			
Mar. 12	0325	2400	MSB, FS, T, LB
13	0000	2400	MSB, FS, B, T
14	0000	2400	MSB, FS, T, LB
15	0000	2400	MSB, FS, T, LB
16	0000	2400	MSB, FS, T, U
Roll No. 68-04			
Apr. 16	0700	2400	U, FS, T, MSB
17	0000	2400	U, FS, MSB, P
18	0000	2400	U, FS, T
19	0000	2400	MSB, FS, U, P
20	0000	2400	MSB, FS, LB, P
Roll No. 68-05			
May 14	0535		T, FS, P
15	0000	2400	LB, P, MSB, T
16	0000	2400	P, FS, MSB
17	0000	2400	P, LB, T, MSB, U, B
18	0000	2400	U, MSB, FS, P, T
Roll No. 68-06			
June 12	0000	2400	MSB, FS, H, T, P
13	0000	2400	MSB, FS, T, P, H
14	0000	2400	MSB, FS, P
15	0000	2400	MSB, P, T, B

0855



1312





Sweep-Frequency Backscatter

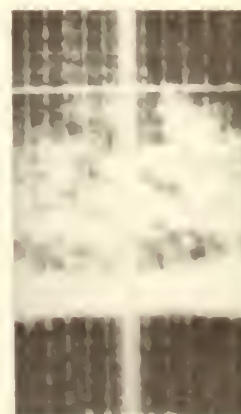
16 mm. Film Data

<u>Year</u>	<u>Month</u>	<u>Days</u>
1954	December	11th
1955	February	9th
1963	January	2-10
1963	February	13-28
1963	March	1- 5
1963	March	8-31
1963	April	1-30
1963	May	1-31
1963	June	4-21

0857



1314

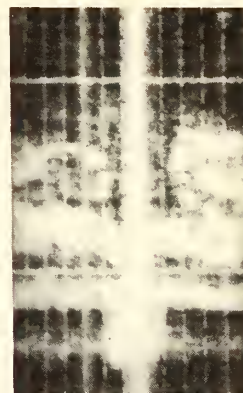


PPI - Rotating Antenna, Fixed-Frequency  
Backscatter - 16 mm Film Data

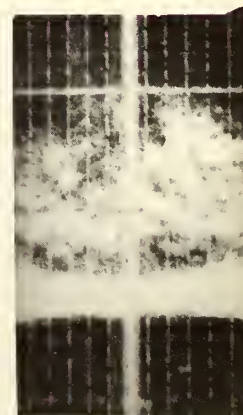
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<u>Date</u>	<u>Start</u>	<u>End</u>
1952		
Roll No. 1		
Dec. 4	0900	
7		0537
Roll No. 2		
Dec. 7	0946	
10		0822
Roll No. 3		
Dec. 10	0833	
13		0152
Roll No. 4		
Dec. 13	0255	
15		1913
Roll No. 5		
Dec. 15	1922	
18		~1200
Roll No. 6		
Dec. 12		0744
Roll No. 7		
Dec. 21	0751	
23		2318
Roll No. 8		
Dec. 23	2326	
26		0640
Roll No. 9		
Dec. 26	1923	
29		1308
Roll No. 10		
Dec. 29	1313	
Jan. 1,		0026
1953		

0901



1316



82809

PPI - Rotating Antenna, Fixed-Frequency  
Backscatter - 16 mm Film Data

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<u>Date</u>	<u>Start</u>	<u>End</u>
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1953

Roll No. 1

Jan. 1	0035	
--------	------	--

3		1754
---	--	------

Roll No. 2

Jan. 3	1802	
--------	------	--

6		0625
---	--	------

Roll No. 3

Jan. 6	0632	
--------	------	--

9		0112
---	--	------

Roll No. 4

Jan. 9	0941	
--------	------	--

11		2356
----	--	------

Roll No. 5

Jan. 12	0009	0414
---------	------	------

19	1740	
----	------	--

22		0212
----	--	------

Roll No. 6

Jan. 22	0222	
---------	------	--

24		1745
----	--	------

Roll No. 7

Jan. 24	1753	
---------	------	--

27		1013
----	--	------

Roll No. 8

Jan. 27	1020	
---------	------	--

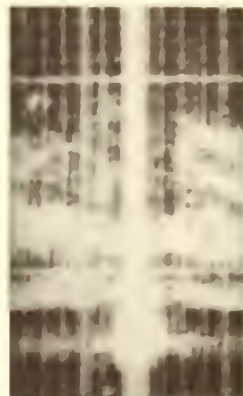
30		0438
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Roll No. 9

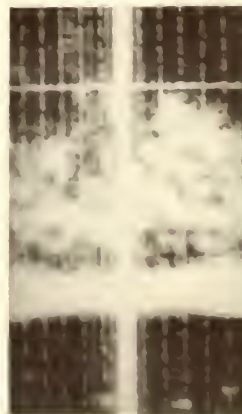
Jan. 30	0604	
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Feb. 2		0055
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0903



1318



82808



Simultaneous oblique sweep-frequency backscatter,  
forward pulse propagation and vertical-incidence  
sounding - 35 mm film data

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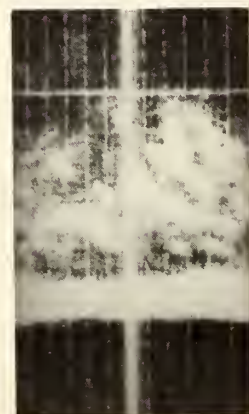
Date

22-23 Sept. 1954  
 29 Sept. 1954  
 15, 19 Oct. 1954  
 22-23 Nov. 1954  
 29 Nov. 1954  
 7-21 Dec. 1954  
 18-21 Dec. 1954  
 3- 4 Jan. 1955  
 11-12 Jan. 1955  
 17-18 Jan. 1955  
 24-25 Jan. 1955  
 31 Jan. 1955  
 1- 2 Feb. 1955  
 7- 8 Feb. 1955  
 17-18 Feb. 1955  
 21 Feb. 1955  
 24-25 Feb. 1955  
 1- 2 Mar. 1955  
 8- 9 Mar. 1955  
 15-16 Mar. 1955  
 22-23 Mar. 1955  
 29-30 Mar. 1955  
 5- 6 Apr. 1955  
 12-13 Apr. 1955  
 19-20 Apr. 1955  
 26-27 Apr. 1955  
 29 Apr. 1955  
 10-11 May 1955

0905



1320



82807

# High-Resolution Range-Time Backscatter Large Negative Film Data

1953

<u>Day</u>	<u>Month</u>	<u>Geographical Azimuth of Antenna Heading</u>
2- 3	June	150°
4- 5	August	040°
11-13	"	150.
13-14	"	040
20-21	"	040
25-26	"	150
26-27	"	040
31 Aug. 1 Sept.		040
9-10	September	040
10-11	"	150
15-16	"	150
16-17	"	040
17-18	"	150
22-25	"	150
29 Sept. - 2 Oct.		150
5-13	October	150
21-23	"	150
26-29	"	150
2- 3	November	150
12-13	"	150
17-18	"	150
17-18	December	150

0907



1322



82806

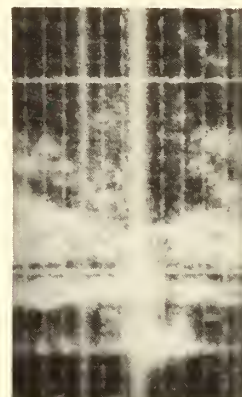
High-Resolution Range-Time Backscatter  
Large Negative Film Data

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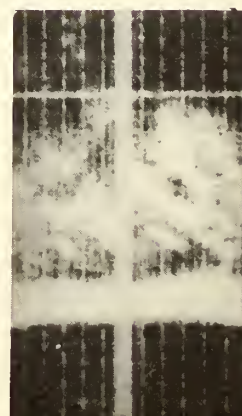
1954

<u>Day</u>	<u>Month</u>	<u>Geographical Azimuth of Antenna Heading</u>
20-22	January	150°
7- 9	February	" "
19-25	March	"
1- 2	April	"
5- 7	"	"
8-13	"	"
14-15	"	"
19-20	"	"
23-30	"	"
30 April - 5 May		"
6- 9	May	"
10-19	"	"
21-25	"	"
1- 2	June	"
3- 4	"	"
7- 9	"	"
15-17	"	"
22-25	"	"
21-22	October	"

0909



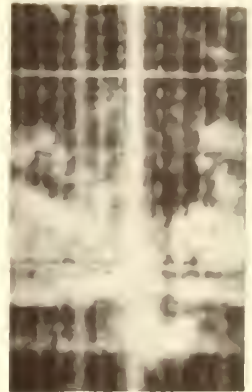
1324



82805



0911

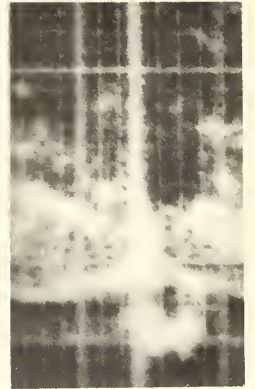


1326

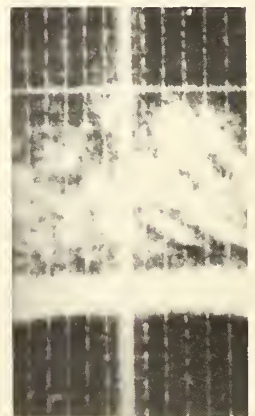


82804

0913



1328



82803

0915



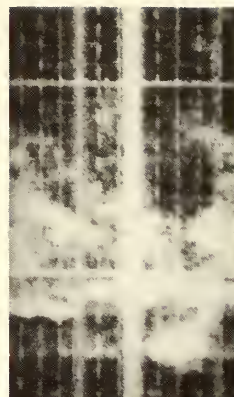
1330



82802



0917

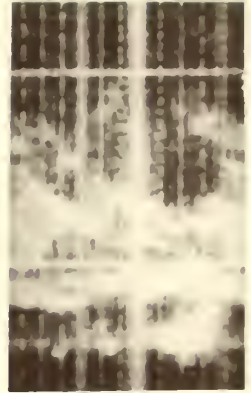


1332



82801

0919

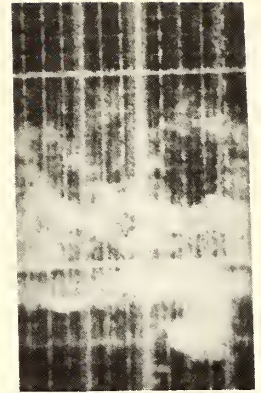


1334

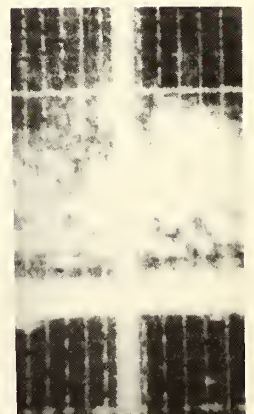


82800

0921



1336



82799



0923

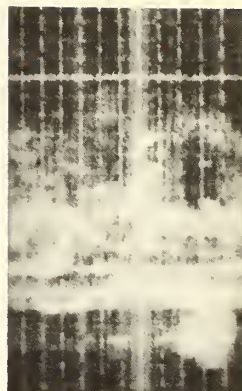


1338



82798

0925



1340



82797

0927



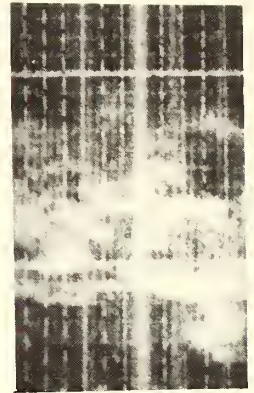
1342



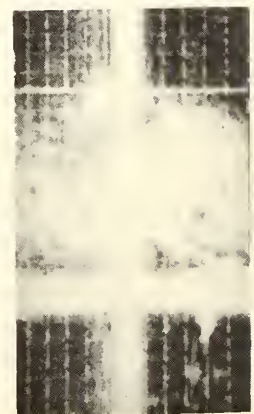
82796



0929



1344



82795



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